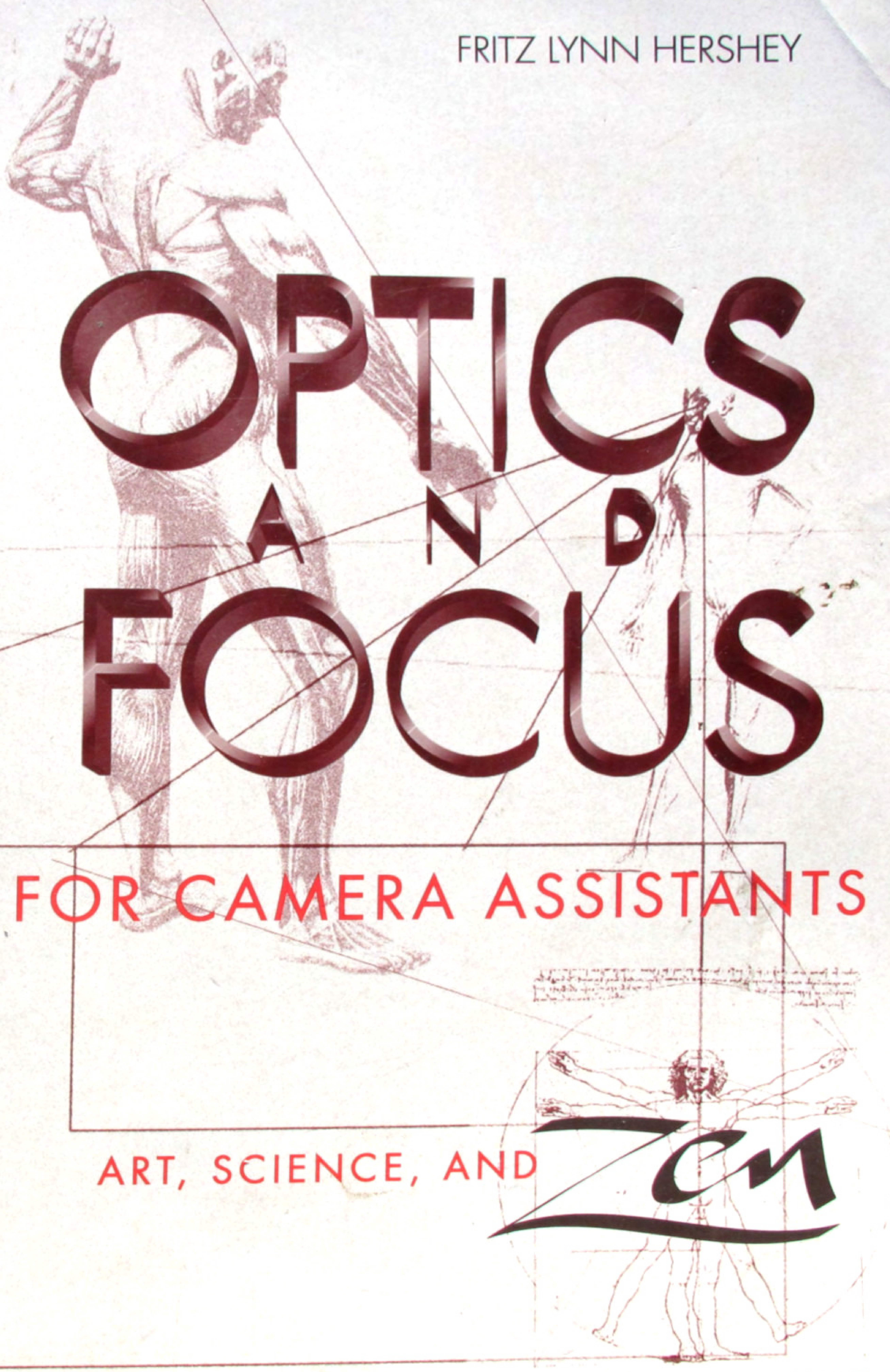
FRITZ LYNN HERSHEY

OPTICS AND FOCUS

FOR CAMERA ASSISTANTS

ART, SCIENCE, AND Zen



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Guerrilla filmmaking . . .

"I didn't have time to get my headphones on, but I know what good sound looks like."

Jeff Call away
Phoenix Grand Prix
Formula One
McClaren Honda
Eyrton Senna: Driver
Gears Communications

Contents

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	Mark Schweickart (operations)
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	Ed Falk (engineering)
	Mark Robinson (engineering)

Birns and Sawyer maintains the best record for service (at prep) in town. Ask any assistant. Way to go, guys!

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Clairmont Camera	Paul Duclose (optical)

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That guy that hung up on me	you know who you are

Introduction

I am not a Zen assistant. I strive to be and that is Zen. This book is by an assistant for assistants. It is about advanced assisting, though a beginner can learn from it, increasing his or her awareness, effectiveness, ability, and growth at an accelerated rate from the outset.

I borrow the word *Zen* and use it loosely, but in my mind aptly, in that this book is meant to help you achieve a very fine and high state in your craft. I like to think of your passage here as transcendental assisting; a "going beyond." It is reaching a point where you can transcend the rules. If you are an advanced assistant, you are at a point in your experience that allows you to know when the rules can and should be broken.

Enter with pride the highest echelon. You are the Delta force and this is guerrilla filmmaking.

This book is not about a totally different kind of assisting. It is not exactly a different approach to assisting. It is about a curve in the road that could not be seen when you embarked at its beginning. Now that you have learned and know all the rules, let us explore their limits and the stretch of those bounds.

This book is a mixture of qualitative views and quantitative technical knowledge. There are excellent books on technical gear and on-the-job procedures. This book is about the art and science of assisting. Here we treat the melding of technical knowledge, skills, techniques, and attitudes into a gestalt. This approach values simplicity aimed toward perfection. It is about stripping down in order to attain, most simply, maximum effectiveness, speed, and precision. So in that it doesn't cover strictly or all technical aspects of assisting, let me say that to have gotten this far and to be here, you must already have a firm grasp of the technical side, or you would have starved to death by now.

This brings us to what the book will cover, what I think are the most vital elements to this "going beyond" kind of assisting. The formula for a better you embraces the priority of "getting the shot." These are the priorities of the director and the DP, the people you are there for. Therefore, these should be your priorities. You can make neat labels and have every tool in its place in your bag, but if the film isn't in the can and the sun's gone down, your painstaking thoroughness is worthless. This is all to the tune of roughly $4,000 per hour, which is the current clock rate of a big-budget commercial crew. And it's only going to go up, thank you. Rather than spread ourselves too thin, we will focus on only a few key elements.

You must get the shot and get it in focus. Focus may not be what they hire you for, but it is what they fire you for. So, we will address focus, speed, and adaptability. Assistants have a bad reputation of being too stiff. This is actually the most true of the beginner, because he hasn't seen enough yet. This book will help those starting, with a small peek at what's going on around the curve in the road, just over the hill. For the rest of you…loosen up!

We will look at the theoretical aspects of focus. We will take a general survey of the major classes of lenses and will look at how their different characteristics interact with the contingencies and criteria of sharp focus.

We will look at the art of estimating focus, on and off the job. We will look at mark-getting and focus-setting techniques that speed setup and increase accuracy. We'll cover conventional and unconventional measuring techniques. We'll look at shot making and the focus pull in normal and extreme circumstances. The "focus sequence" will be tailored and applied to a broad spectrum of different shooting situations. This is the "how." For the "when" of getting and giving, it is better to give than to receive. Special aids to focus will be discussed. Focus cues in complex blocking, use of the "focus circle" data, cybernetics, and the Zen of seeing without your eyes will all be covered. Dolly and crane moves are treated with rigorous, systematic techniques for complex blocking in two- and three-dimensional space. Built-in dynamics of lens design can aid you in pulling at the right tempo according to speed and distance of approaching or receding objects. We'll discuss how to judge your own performance and accuracy after the shot. This is when you can be the hero or the goat. The editor and the director will always be guaranteed some choices and some "keepers."

After we've got our act together, we're going to put it on the road. We'll look at the different shoots, their milieus and the requirements of each, and where guerrilla techniques apply to varying degrees. We'll take our focus sequence and show how different steps in the sequence

may be omitted as we tune and tailor it to each different shoot venue. In the studio we'll "run speedwork" with a second assistant. Out in the field, we'll look at total preparation: mind/body, sports and the "speed bag," and the weather (lenses can get hot too—and cold).

The final sections will make up a "bag of tricks" to take with you. We'll just do a little "mopping up" as we send you out into a sometimes very cruel world. We'll give you something to carry inside with you: attitudes for success, how to deal with failure, and anticipation of that all important next time. If you stay in this field, you will get crushed. There will be times when you can't win, but you'll know what to do. You won't let the monkeys get you. It is my intuition that a trait shared by the best is the desire to be the best.

Welcome!

1

The Lens

LENS FUNCTION AND RELATED MECHANICS

Focus (roughly) is the intersection of light rays to form an image. Focus is dependent on the positional adjustment of the lens and the viewing system, which looks through the lens. Focus is also dependent on the humans who twist the helical mount on the lens and view the effects of this adjustment through a reflex viewing system. It is interdependent with the depth of field, a special case of which is hyperfocal distance. Both of these are functions of the combined interactions of focal length and the aperture setting on the lens. Depth-of-field limits except for hyperfocal distance are also a function of object-distance-based lens focus (critical focus). The aperture setting interacts with the relative effect of aberrations, of which there are seven kinds. They are present to varying degrees in every "corrected" lens. Aperture also affects diffraction.

These technical issues are addressed and explained in this book, and they should be understood by you. Take advantage of this space you have in time, in a learning environment, to grow strong and prepare yourself. The better you understand the theory, the better you will practice your craft when there's no time to think and little patience with feelings, when in the heat of battle you hear, "Focus! Focus!" and the operator is shouting, grabbing at the follow-focus knob. Barring this display, he looks up from the lens and says, "It's soft." Or, "The whole thing was soft." Or during a long tracking shot, he is saying, "Good... Good... Soft... Soft! Soft!" Do you throw up your hands? You want to. A lot of the shot was bad anyway. No. You keep pulling. (*Pulling* is assistant's jargon for focusing, or twisting the focus collar on a lens.)

Pull it back in. You can save part of the shot. In some instances, you may have just had your only chance at the shot, anyway. Don't be distracted from your task by self-defeating bad feelings. You must focus your feelings and your mind to better focus the lens and the shot. Toward that end, you must be as strong as you can be technically.

LENS THEORY

Focus

So let's start with the theoretical, technical/mechanical aspect of that all-important word, *focus*. Focus is what is not occurring as the operator is clucking that bad news into your burning ears. But what is focus?

Focus is the primary function of a lens and of an assistant. According to Nussbaum in *Geometric Optics: An Introduction*: "One function of any lens, or optical system, is to take all the rays leaving each point at the object and focus them to a point in the image." This is also your job. I believe it is your primary function. It is possible for you to do this because, "All rays leaving an object at point P and passing through the lens will meet again at P'. This is what we want a lens to accomplish."[1] This is also what we want an assistant to accomplish. The assistant and the lens both share the task of establishing focus. They work closely together to accomplish this. The lens will never be aware of you, you must be hyper-aware of it. Appreciate it for what a simple, yet fabulously complex entity it is. It and its function are probably the most pivotal reason for your job. Make focus your job. If you don't, you'll find production will swiftly make it somebody else's.

Here are some good definitions of focus. Focus is "a point at which rays (as of light, heat, sound, etc.) converge, or from which they diverge. Specifically, it is the point where geometrical lines, or their prolongations conforming to the rays, diverging from or converging toward another point, intersect and give rise to an image after reflection by a mirror or refraction by a lens or optical system."[2] See Figure 1-1.

Andreas Feininger, in *The Complete Photographer*, says, "To properly focus a camera, the distance between the lens and the film must be adjusted in accordance with the distance between the subject and the lens." This is done with the aid of two devices. He lists as number one "a mechanical device…in most small format cameras a helical lens mount…"[3] This adjusts the distal relationship of the lens to the focal plane, or film plane. By "small-format cameras" Feininger means the group that includes 35mm and 16mm cameras and film formats.

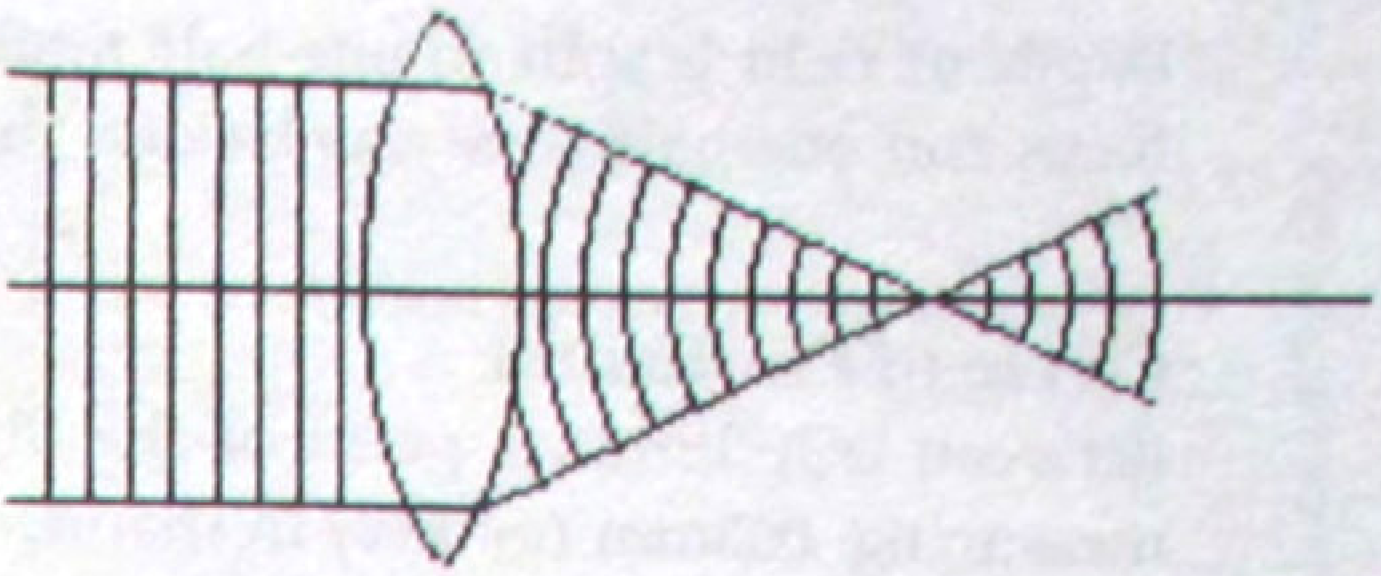
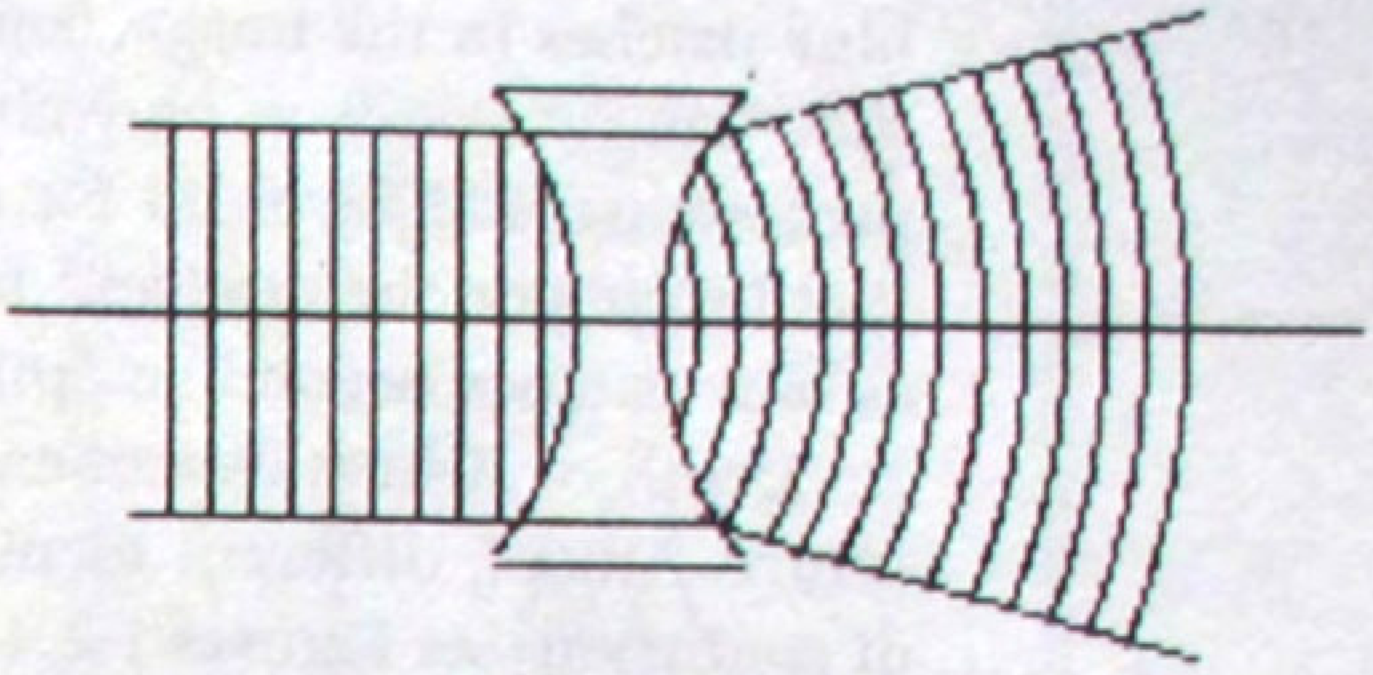


Figure 1-1.
Focus. Rays from an object point at infinity and converge to an image point after refraction.



Feininger lists as the second focus aid "an optical control, which tells the photographer when the distance between the lens and the film is properly adjusted."[4] This is the viewing system. In film we use an optical reflex system. If focus marks are arrived at or checked "by eye," the assistant and sometimes the operator become part of that system. So I am adding to Feininger here by saying that focus is attained with the aid of three devices: (1) the helical lens mount, (2) the viewing system, and (3) the assistant. *Webster's Third New International Dictionary* lists the word *focuser.* It means "one that focuses or aids in focus."

Depth of Field (DOF)

A core concept of focus is depth of field and the related concept of hyperfocal distance. "Objects that are within a certain range, which is called the depth of field, are focused to relatively sharp images . . ."[5] (on the focal/film plane). Depth of field is "a degree of latitude in the position of an object, while still retaining sharp focus on sensitive material [held] in a fixed position in a camera."[6] The distance between the front and rear limits of the range of this object positioning is the depth of field. Depth of field falls in a zone that extends to one-third its total zone size in front of object focus and two-thirds total zone size behind the object focus. In extreme close-ups this relationship breaks down.

Depth of field is split to one-half total zone size in front of the object focus and one-half zone size behind the object focus.

Circle of Confusion

Between DOF limits, a point of the object will be rendered as a circle measuring .025mm (or less) in diameter for 35mm lenses and .0125mm (or less) in diameter for 16mm lenses. This is known as the circle of confusion (COC). The specification numbers for both formats represent the maximal limits of the acceptable rendering of points of the object as blur patches in the image. Some lenses exceed this performance. Those that "image" points as blur circles larger than these areas do not meet professional standards set for a lens's performance. Points of the object that lie outside the near and far limits of depth of field will be imaged as blur patches beyond acceptable limits by even the sharpest lens.

Depth of field is dependent on object distance, focal length, and aperture. Among different formats, DOF depends on different size circles of confusion. See Figures 1-2, 1-3, and 1-4.

The speed of the edge of the disk represents the rate of angular sweep of the converging ray through D.O. Focus. The number of revolutions of a small disk (size of D.O. Focus) that is driven by the large disk as it rotates through one revolution is the speed of the large disk edge; and it is the rate of angular sweep through D.O. Focus. For each focal length, the large disk turns the small disk approximately 4 times faster than is the case for a focal length one-half its value.

The largest disk (50mm) edge travels approximately 17 times faster than the largest disk edge (12.5mm). These relationships analogize those above of *vertical internal angle change* through $T\ (50\text{mm}) = S - R = 2.5''$ $\approx 4^2 T\ (12.5\text{mm}) = S - R = 42''$ and *image distance increase*: image distance (u) (50mm) increases $\approx 17 \times$ image distance (u) (12.5mm) increases u (50mm) increases $\approx$ 17u (12.5mm) increases.

Object Distance

The farther away from the lens the object focused on is, the greater the range between front and rear limits of acceptably sharp focus. Simply, the greater the object distance, the greater the depth of field. Light rays emanating from a point source diverge at a more narrow angle, presenting a decreased angle of incidence (to the normal). After refraction, these rays converge at a more narrow angle toward their focal point. This results in smaller blur circles that are the intersections of converging light rays and the focal plane. The blur circles are the cross sections of focusing cones of light and are created by the intersection of light cones and the focal plane. These smaller blur circles are more apt to

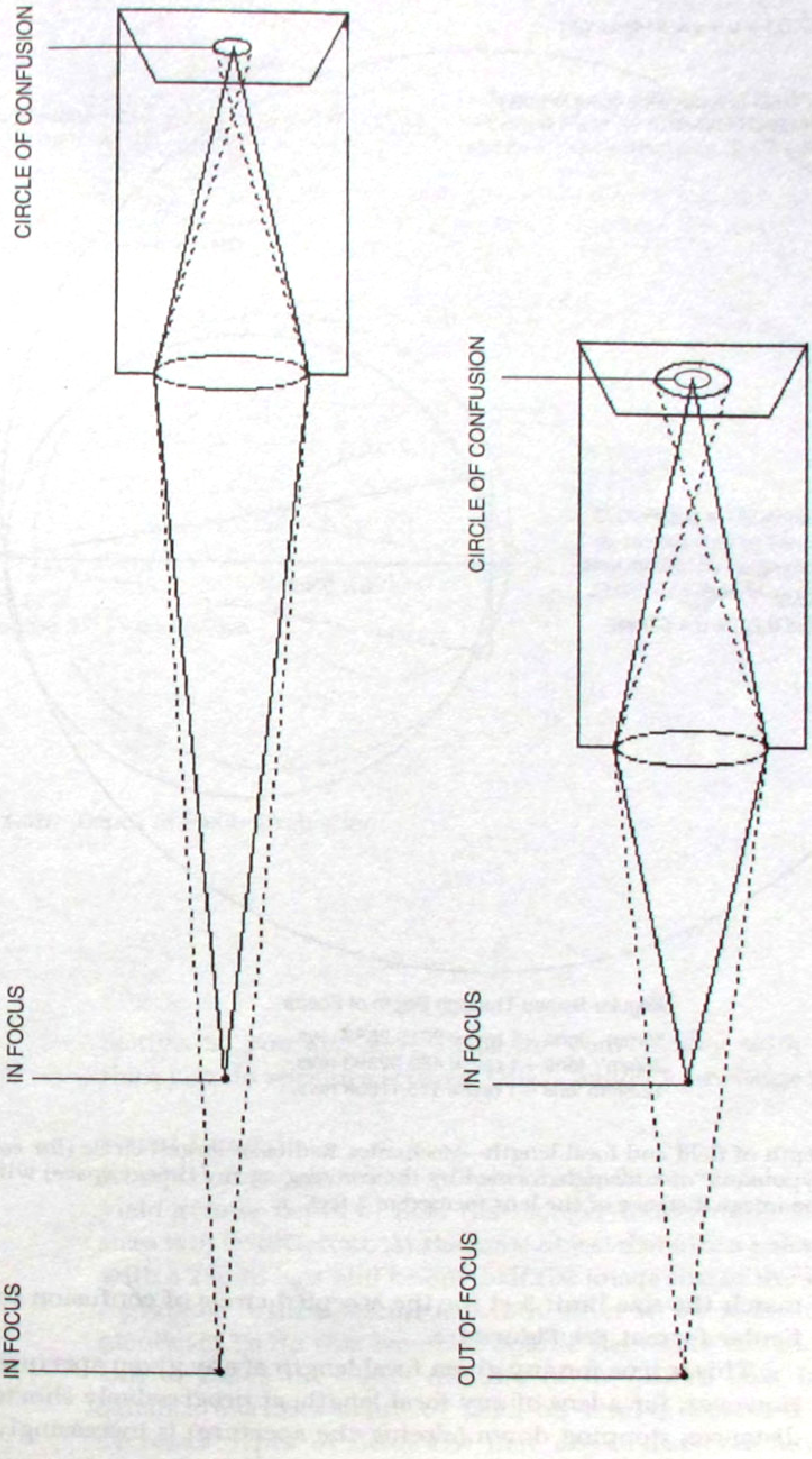


Figure 1-2. Increased object distance means increased depth of field. This is because light rays impinge at the lens and at the image plane at smaller angles to the normal.

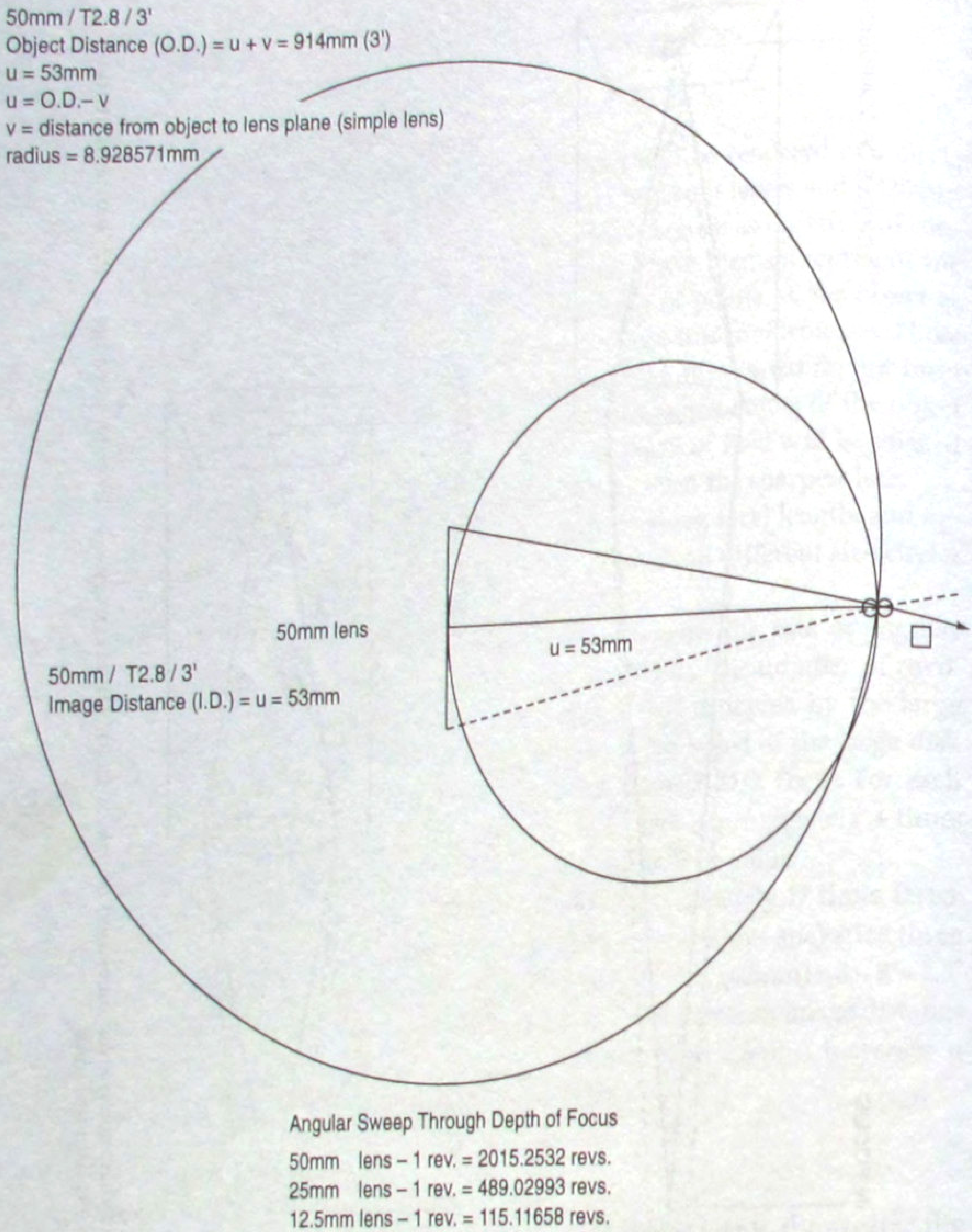


Figure 1-3a. Depth of field and focal length—Mechanics. Radius of largest circle (for each lens) represents the hypotenuse of a triangle formed by the converging ray (image space) with the lens plane and the image distance of the lens focused at 3 feet.

match the size limit 5-et for the accepted circle of confusion for a particular format. See Figure 1-2.

This is true for any given focal length at any given aperture setting. However, for a lens of any focal length, at progressively shorter object distances, stopping down (closing the aperture) is increasingly less ef-

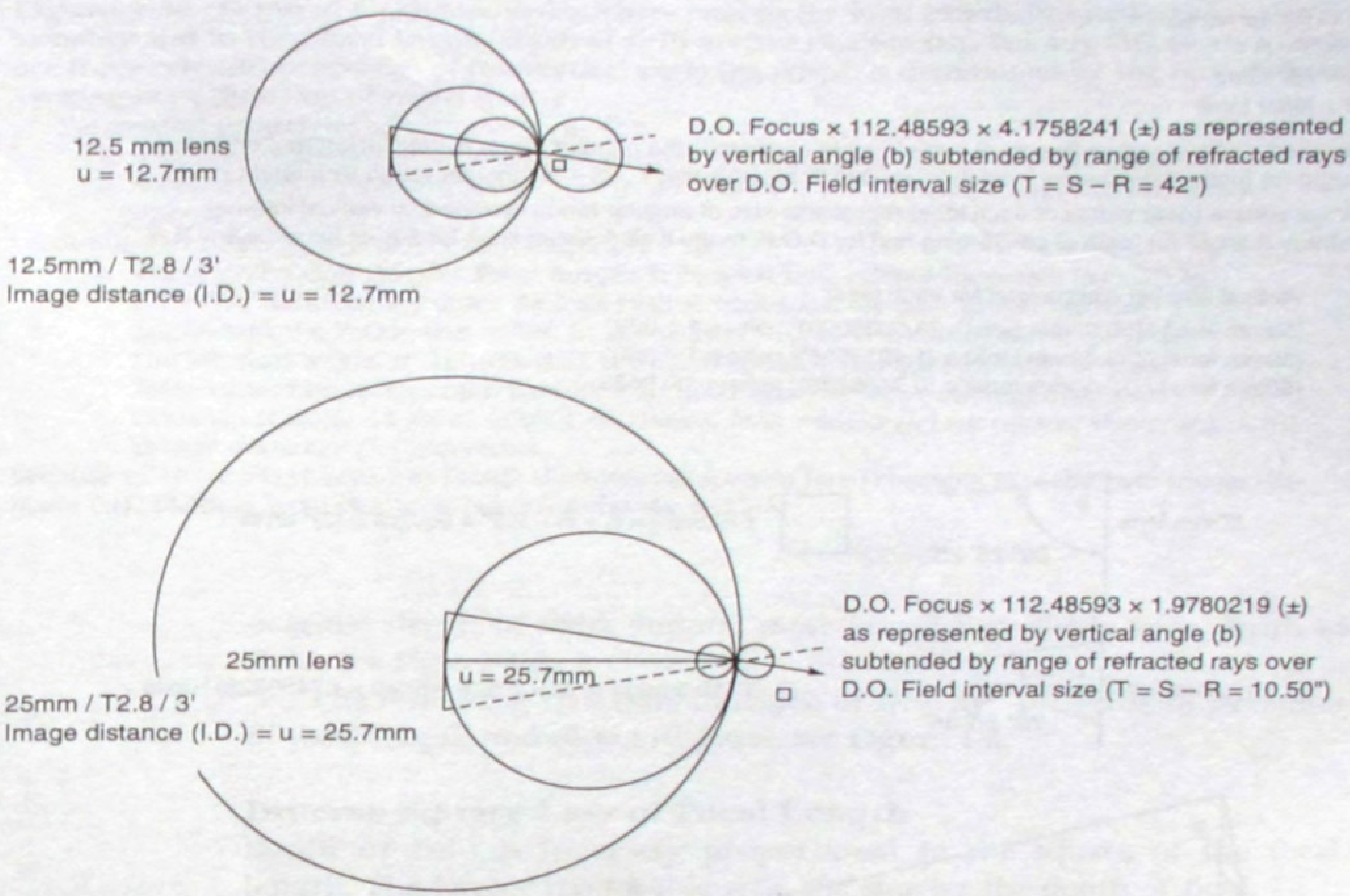


Figure 1-3b. Depth of Field—Mechanics.

fective. So you get more focus for your money with object distance than you do aperture setting. This is handy knowledge in sports work.

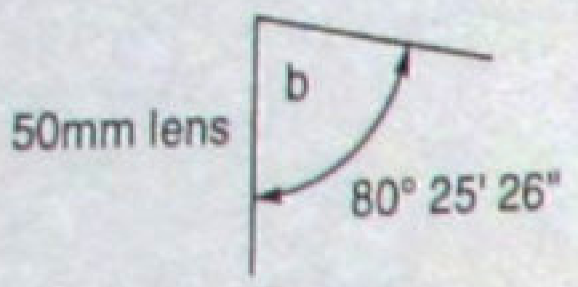
Focal Length

At equal object distances and apertures, shorter-focal-length lenses will yield greater depth of field than longer-focal-length lenses. The image sizes will be different. At the same object distance a ruler photographed with a 25mm lens will be one-half the image size of the same ruler photographed with a 50mm lens. But what if we make the image sizes identical? To do this we must double the object distance of the 50mm lens or halve the object distance of the 25mm lens. Increased object distance increases depth of field; obversely, decreased object distance decreases depth of field. The new object distances have restored the

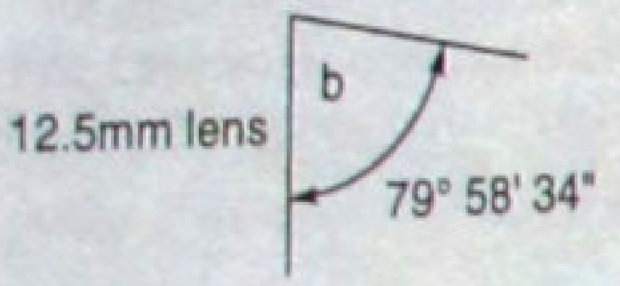
D.O.F interval size = T
T = S – R
S = Far Limit
R = Near Limit

Smallest circle at vertex (focus) of each triangle represents the angular range of vertical internal refracted angle (b) [path of converging ray] through D.O.F. range limits: T = S – R (angular range by interval size).
Small square (near vertex of each lens) represents size of angular range spanned by vertical internal refracted angle (b) [path of converging ray] for D.O.F. range limit (interval size) for 50mm lens: T= S – R = 2.5"

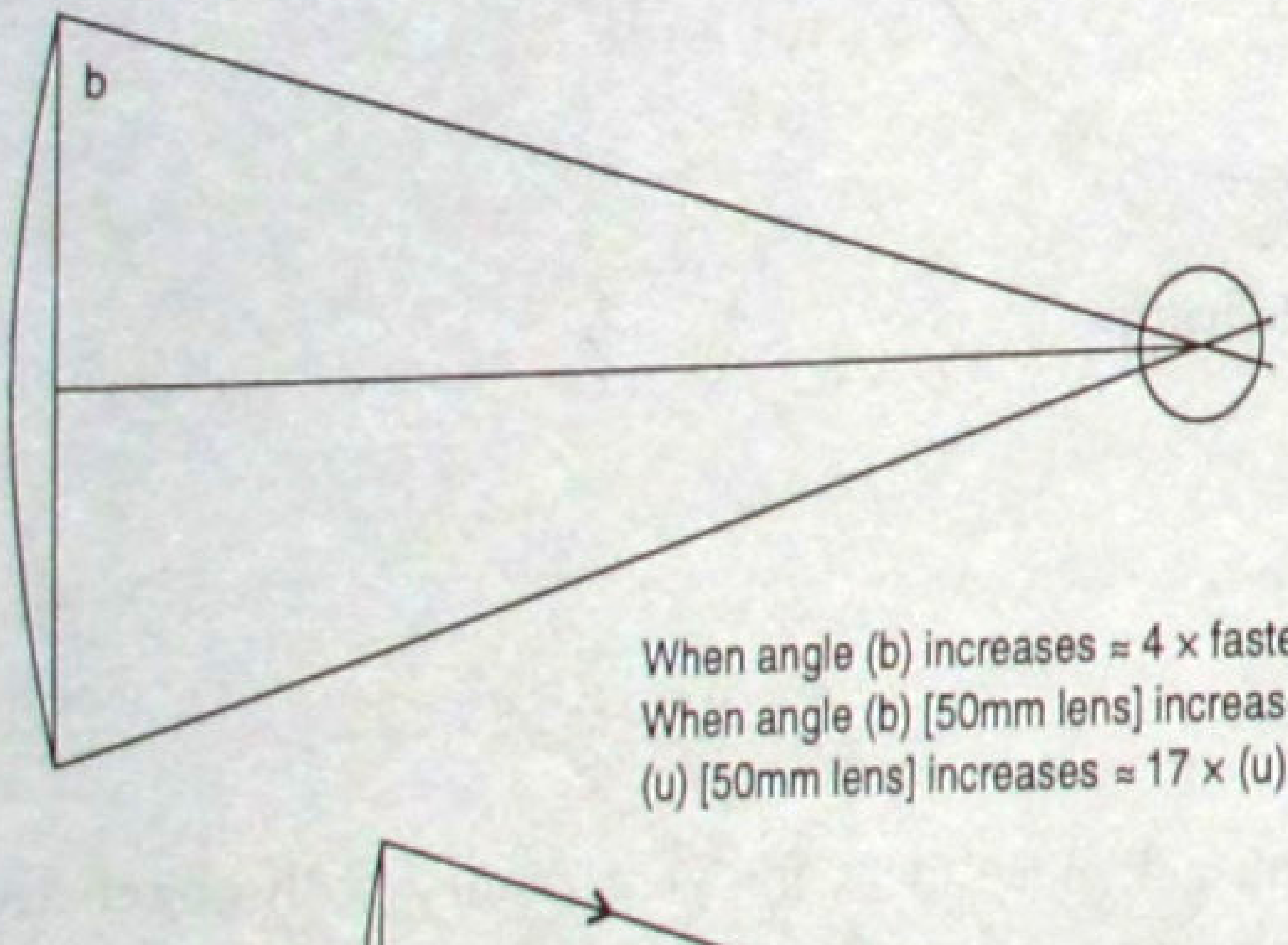
Vertical angular comparison for each lens:
[50mm lens] / [50.00mm lens] = $(3.0000000)^2$ units = 1:1.000
[50mm lens] / [25.00mm lens] = $(1.4913656)^2$ units = 1:0.250
[50mm lens] / [12.50mm lens] = $(0.7456828)^2$ units = 1:0.0625



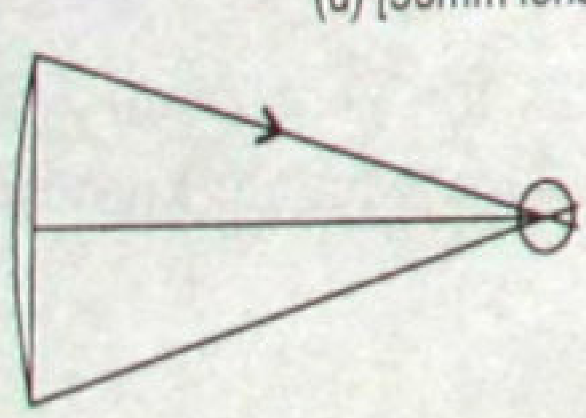
T [50mm] = S – R = 2.5" = square = $(3)^2$ units



□ T [12.5mm] / ≈ 4^2 = 2.5" = square = $(.7456828)^2$ units



When angle (b) increases ≈ 4 × faster, (u) increases ≈ 17 × faster.
When angle (b) [50mm lens] increases ≈ 4 × angle (b) [12.5mm lens],
(u) [50mm lens] increases ≈ 17 × (u) [12.5mm lens].



D.O. Focus x 112.48593 x 1 (±), as represented by vertical angle (b) subtended by the range of refracted rays over D.O. Field interval size (T = S – R = 2.5 ")

Figure 1-3c. Depth of Field—Mechanics. Three reasons for focal length/image distance proportionality and in turn focal length/depth of field inverse relationship. For any O.D. (u + v), there are three relevant properties of the vertical angle (b), which is determined by the refracted converging ray's direction of travel (path):

Tangential properties of vertical angle (b):

1. Vertical angle (b) [50 mm lens] is greater than vertical angle (b) [12.5mm lens].
2. Vertical angle (b) [50mm lens] opens 4 × the rate vertical angle (b) [12.5mm lens] opens.

Cotangential property of vertical angle (b):

3. For a given aperture, as focal length increases, lens radius increases (available effective incident surface). As lens radius increases, for any given vertical angle, and we relate this value to the numerator of the cotangential ratio of the vertical angle, it follows that the denominator (image distance) of this ratio must increase proportionately to maintain the same cotangential relationship (ratio). *As focal length increases, lens radius (a) increases; therefore, image distance (b) increases.*

Because of these three reasons, image distance (u) [50mm lens] changes 17 × the rate image distance (u) [12.5mm lens] changes, per unit change in O.D.

original depth of field. Simply: same image size yields same depth of field. See Figure 1-5.

The following two laws of depth of field are anchored in variables of focal length and object distance. See Figure 1-6.

Inverse Square Law of Focal Length

Depth of field is inversely proportional to the square of the focal length. The longer the focal length, the shorter the depth of field.

$F^2(DOF) = 1$

Proportional Law of Object Distance

Depth of field is proportional to the square of the times the object distance is increased. The higher the footage focused on the lens the longer the depth of field.

$(DOF)/d^2 = 1$

d = object distance

Relating these two laws mathematically, we can see that in restoring identical image size to those images projected by lenses of different focal lengths, we also restore to them identical depth of field, given identical apertures.

Depth of Field and Image Size

Depth of field, focal length, and image size are a constant. This means *same image size equals same depth of field* (at same aperture). If

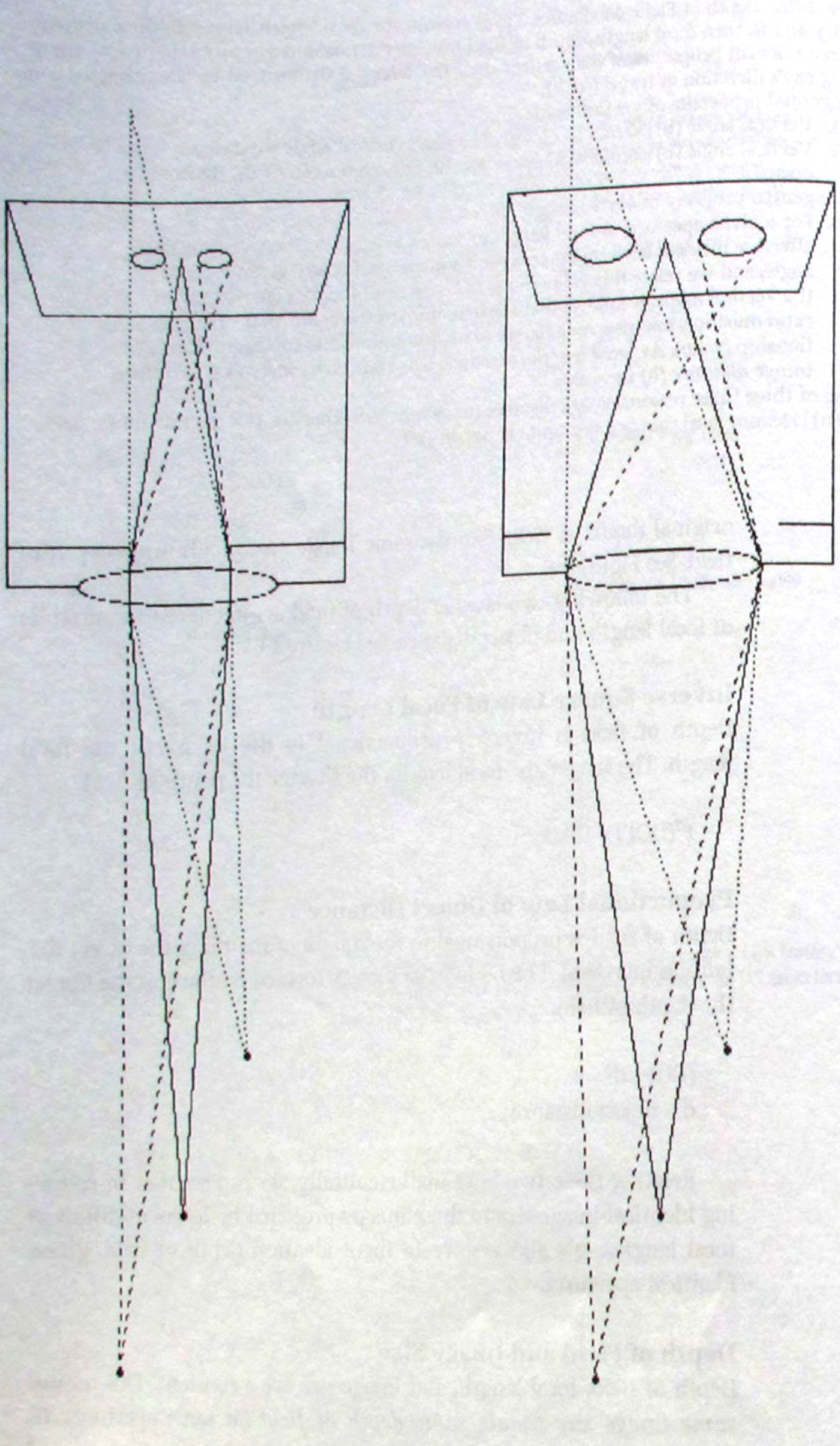


Figure 1-4. Depth of field is increased as aperture size is reduced. Only light rays (impinging at the lens and at the image plane) traveling at smaller angles (to the normal) are allowed to pass through a smaller aperture. These smaller angles form narrower cones that approach or match the size of the circle of confusion.

F = focal length

$$F = \left(\frac{1}{2}\right) = \left(\frac{2}{1}\right)^2 F = \frac{4}{1}\ F = 4 \times DOF$$

$$\times$$
$$4$$
$$\downarrow$$

$$F = \left(\frac{1}{4}\right) = \left(\frac{4}{1}\right)^2 F = \frac{16}{1}\ F = 16 \times DOF$$

Figure 1-5. Reducing focal length by one-half increased depth of field four times.

Focal Length (f)	100mm	50mm	25mm
Depth of Field (Index Numbers)*	$\frac{1}{10{,}000}$	$\frac{1}{2500}$	$\frac{1}{625}$

$$f = \left(\frac{1}{2}\right) = \left(\frac{2}{1}\right)^2 f = \frac{4}{1} f = 4 \times DOF$$

$$f = \left(\frac{1}{4}\right) = \left(\frac{4}{1}\right)^2 f = \frac{16}{1} f = 16 \times DOF$$

*Index numbers are for demonstration purposes only.

$$f(2) = \left(\frac{1}{2}\right)^2 f = \frac{1}{4} f$$

$$\times \qquad\qquad \times$$
$$2 \qquad\qquad 1/4$$
$$\downarrow \qquad\qquad \downarrow$$

$$f(4) = \left(\frac{1}{4}\right)^2 f = \frac{1}{16} f$$

Figure 1-6. Increasing the focal length by two reduces the depth of field to one-quarter its original size.

$F^2(DOF) = 1$ (inverse square law of focal length) and $(DOF)/d^2 = 1$ (proportional law of object distance) then:

$F^2(DOF) = (DOF)/d^2$
$[F^2(DOF)]/1 = (DOF)/d^2$
$DOF = d^2F^2(DOF)$
$(DOF)/(DOF) = d^2F^2$
$d^2F^2 = 1[(DOF)/(DOF)]$
$d^2F^2 = 1$

The perspectives of lenses of different focal length yielding the same image sizes will be different, however.

Other handy guides can be derived from these two related laws. As their relationship is one of trading off, you can take advantage of this when trading focal length for object distance and vice versa.

From the focal length law:

If we reduce focal length by one-half, we increase the depth of field four times. See Figure 1-5.

If we reduce the focal length to one-quarter of its original value, we increase the depth of field sixteen times.

Conversely, if we increase the focal length by two, we decrease the depth of field to one-quarter of its former size. See Figure 1-6.

If we increase the focal length by four, we decrease the depth of field to one-sixteenth of its previous length. See Figure 1-7.

From the object distance law:

If we double the object distance to the lens, we increase the depth of field four times.

If we increase the object distance three times, we increase the depth of field nine times.

If we increase the object distance four times we increase the depth of field sixteen times.

And we assistants do love to increase that depth of field! But wait! There's more.

OD = Object Distance

$(OD) \times 2 = (2(OD))^2 = 4$ DOF

$(OD) \times 3 = (3(OD))^2 = 9$ DOF

$(OD) \times 4 = (4(OD))^2 = 16$ DOF

DOF changes by the square of the change in object distance.

$x = 4 = (\text{times distance increase}) = (2)^2 = x = 4$

$$\frac{1}{2500} \times \frac{4}{1} = \frac{4}{2500} = \text{original DOF} = \frac{1}{625}, \text{ is four times larger than } \frac{1}{2500}$$

Figure 1-7. Focal length observes an inverse relationship.

Aperture

We can also alter the depth of field by changing the aperture setting on the lens.

We know that as we increase the f-stop numbers or T-stop numbers on the lens, we are making the aperture smaller. We also know that decreasing aperture size increases depth of field. How much does it increase depth of field? We know that closing the aperture down does not buy as much relative depth of field as increasing object distance or decreasing focal length. In physics just about everything is relative, but what is that relationship? If you double the f-stop number or the T-stop number, which means decreasing light allowed to one-quarter the original amount, you double the depth of field.

A brief digression here: You know that f-numbers or T-stop numbers marked on the lens relate to image brightness as a function of light transmitted by the lens through the aperture. T-stops refer to the actual amount of light transmitted.

The f-numbers relate to this factor, in that they represent a ratio of lens diameter to focal length (more later). For now it's important to know that the series of f-numbers or T-stops chosen for use on motion-picture lenses relate to each other based on the number 2. This is easily seen on the lens, in that every other stop is double or half the numerical value of every other stop. Each f or T number is the square or square root of each f or T number immediately before or after it. See Figure 1-8. This is due to the inverse square relationship between brightness and f-numbers and the square relationship between brightness and relative apertures. But more about that later. For now, you can get a feel for how much depth of field you are gaining or losing (yikes!) with a change in stop just by looking right at the lens in front of you.

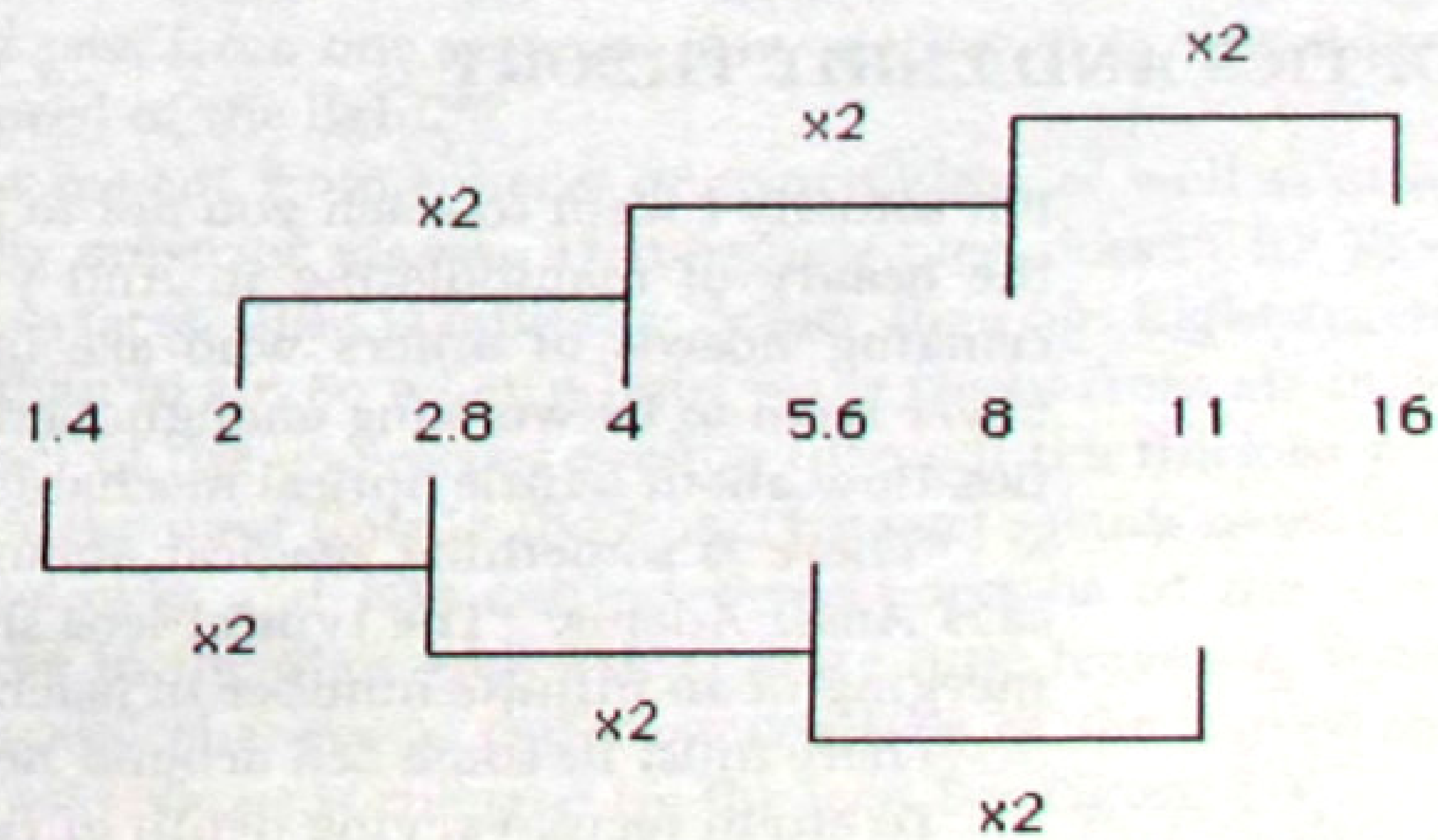


Figure 1-8.
When lens focus equals H, depth of field extends from one-half (H) to infinity.

For example, you're shooting a car race at T11. The sun goes behind a cloud and you open up two stops. You halve your aperture number (f-stop number). You halve depth of field, as follows:

T11 × ½ = T5.6

The number you must multiply your original stop by to get your new stop is the factor by which you must multiply your original depth of field to get your new depth of field.

Hyperfocal Distance

We have seen what depth of field is, how to think about it, and how to regulate it. Now let us look at a special case of depth of field and how to maximize it.

This is the hyperfocal distance. On a lens when principal focus is set at infinity, the near limit of depth of field is the hyperfocal distance. All points from this distance to infinity will produce an image or blur circle ≤0.25mm in 35mm, and ≤.0125mm in 16mm. Remember, these blur circles are the same as the circles of confusion discussed earlier. (Hard-core, eh? Get used to it, kid.) This means that all objects from this near point to infinity will be rendered in sharp focus. But wait! It gets even better. If the lens's principal focus is now changed from infinity to this near point (hyperfocal distance), all objects from infinity to one-half the hyperfocal distance will be in sharp focus. You have attained maximum depth of field for this lens, minimizing the extent to which you must pull focus. Remember, as soon as you touch the lens, if you mess up, kid, it's your fault! This is a concept Hollywood loves, because that makes it not their fault and everyone can keep their Porsches.

OPTICS AND LIGHT THEORY

But actually I want to teach you not to be afraid of the lens and to love the beauty of manipulating it. And you will rise above the fearful, cringing hoards of others who are in a perpetual slow period and never seem to be working enough. Let's move on to other harsh realities. How about a little optical mechanics?

"There is something magical about the image formed by a lens," says Ansel Adams.[7] "The typical lens shape is given by the continuous merging of an infinite number of [such] prisms," says Baines.[8]

There must be some Zen around here, somewhere.

To attain focus, varying depth of field, and varying hyperfocal distances for objects of varying sizes, distances, and even speeds, under

varying amounts of light, we vary *focal length* and *aperture*. These two elements are the primary criteria to be considered in our varying choice of lenses.

"But, in spite of all the science and technology that underlies our medium, the sensitive photographer feels his images in a plastic sense," observes Adams.[9]

So should we ignore the hardware? We're assistants. Hardware is a big part of our job description. But what about the Zen? To get there, to fly, we must study the fundamentals so well that, according to Adams, "we must come to know intuitively what our lenses and other equipment will do for us, and how to use them."[10] On the need to go deeply into design and manufacturing, however, Adams says no, "But the photographer who understands the concept of lens function will certainly benefit in his work."[11] So from the sublime to the mundane. Let's look at that now.

First, let's establish that light can be thought of as traveling in a wave. "A lens is a device used to alter the shape of a wavefront," according to John Betts.[12]

For us, lenses are transparent objects, made of glass, having two smooth surfaces. The surfaces are convex or concave, converging or diverging, positive or negative in their effect on the wavefront. Baines says, "A lens is a device whereby a large cone of light from a point may traverse a large disc and be refracted, so that it is once more concentrated to a point to give a very bright sharp image."[13] See Figure 1-1.

This is called refraction. As light rays pass from one medium to another on an incidental path, in this case from air into glass, their angular change in direction is called refraction. Or more formally:

"When a wave passes from one medium to another, its frequency remains the same, but its speed and wavelength change. As a result the wavefront is bent at the boundary. This bending of the wavefront is called refraction."[14] Or, more simply: "Refraction is the bending of light rays when they pass from one material into another. It is caused by a change in the speed of the light."[15]

Movie lenses are cut from spheres of crown glass, as well as other types of optically superior glasses. That sounds nice, doesn't it? They have spherical surfaces. Glass is optically denser than air. Light travels slower in glass than in air. So when a light wave passes from air into a glass lens, the part of the wavefront passing through the thickest part of the lens spends the most time in the lens. This part spends more time traveling more slowly and lags behind those portions of the wave spending less time in the glass and, hence, more time traveling faster. Due to various speed changes in different portions of the wavefront, the shape of the wavefront is changed by the lens. See Figure 1-9.

So refraction is dependent on the shape of the lens. Shape deter-

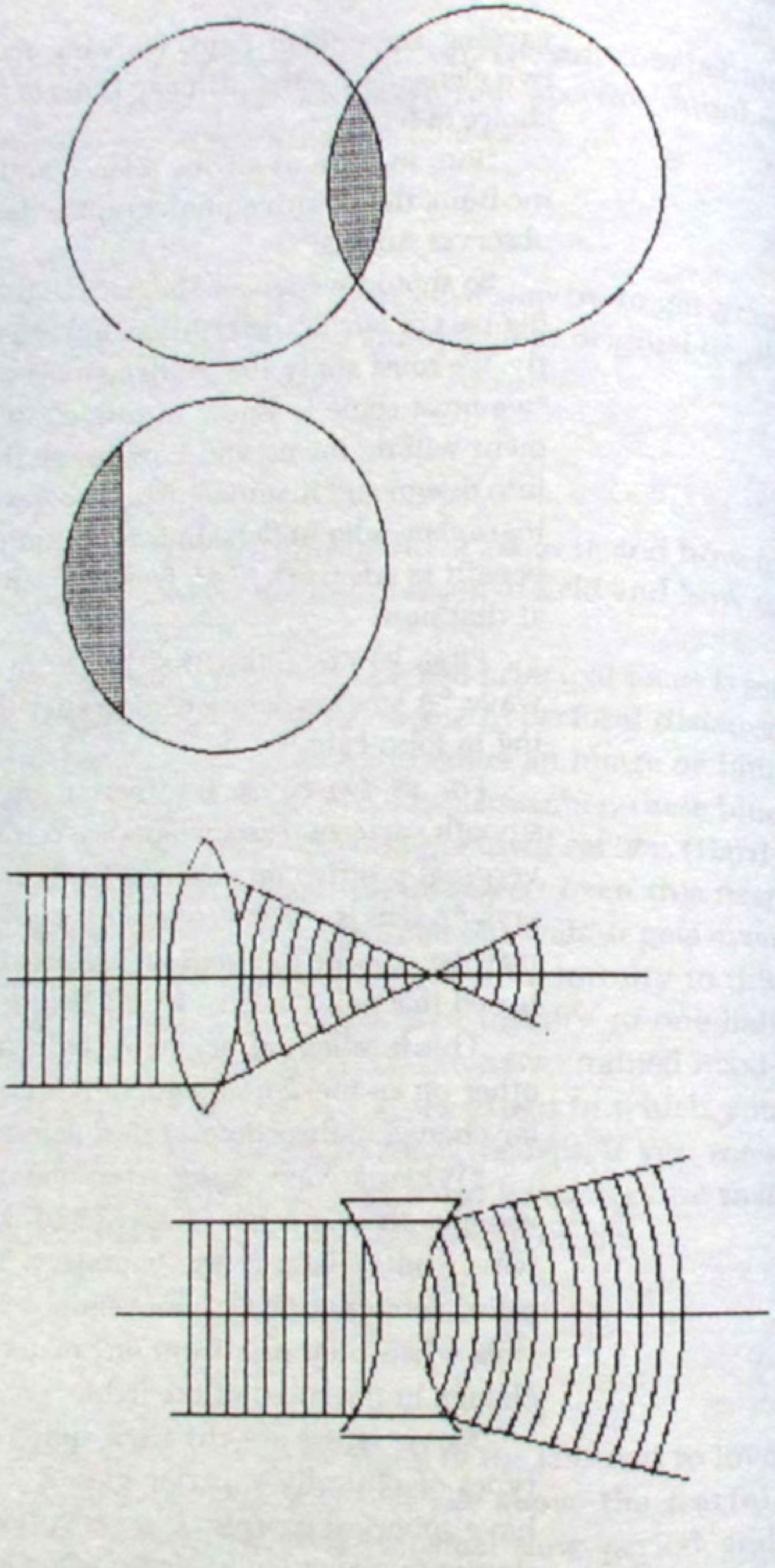


Figure 1-9.
A converging lens is a section of a sphere, as is a diverging lens.

mines, in part, the angle of incidence and also, in part, the amount of refraction. Refraction is also determined by varying densities of different glasses, compared to that of air. This determines the inverse relationship of the speed of light through air. This relationship, or number (AIR/MEDIUM), is called the refractive index. Light through crown glass travels at about two-thirds the rate of its speed through air. The

inverse of this is its refractive index. Hence, the refractive index of crown glass is 1.5. But who cares, right? Where's the coffee? What's for lunch? And these aren't Coronas. Here is an example for refractive index (RI).

Speed of light through air = 1
Speed of light through crown glass = 2/3
RI = speed of light through [air/medium(crown glass)]
RI = 1/(2/3) = 3/2 = 1.5

There is no refraction of a ray passing through a surface at 90 degrees to the plane of that surface. There is greatest refraction of those rays passing through surfaces at the most acute angles of incidence. These angular relationships are the reason why a lens makes all your twisting come out in focus.

Because of the glass, its shape, and the angle of incidence at which the light hits it, a lens refracts light to form an image. A sharp image, right? This is the part of theory we want to realize. But how does a lens get all that light to focus? How does it make a point object a point image? Photographic lenses, also called complex lenses, are made up of negative diverging lenses, which direct light rays away from a central point, and positive converging lenses, which direct light rays toward a central point. The combining of negative diverging lenses and positive converging lenses results in compound positive lenses. They converge the scattering light rays emanating from a point object back into a point again. On a complex object (like your thumb, you big dumb guy), the rays of light emanating and scattering from all points on the object are gathered, and the light is rearranged back into the same pattern as the object. This rearrangement is called an image. The converging lens that does this is a section of a sphere, remember?

Image formation is due to spherical shape. A lens is shaped to allow rays, impinging on different areas of the lens, to be refracted to different degrees. This is the secret of a lens's ability to converge rays in a way that will form an image.

"When those curved lens surfaces are segments of spheres, the angles presented to incidental rays will be such that every light ray emanating from an object and striking any part of the face of the lens, will be refracted just enough so that all will reach the same image point."[16]

Some people feel that you can ignore how a lens forms an image and still make an intelligent lens choice, and they're right. I just need more pages for my book. They say you don't need to know terms like node of emission, chromatic aberration, coma, and so on. Well, that may be. Again, according to Ansel Adams: "But the photographer who un-

derstands the concept of lens function will certainly benefit in his work."[17] Thank you, Ansel.

Awareness is a Zen-like concept, and without a physicist's grasp of certain technical contingencies, but with a good feel for the concepts, you are more whole and just that little bit better off. In social psychology and learning theory, there is a firm tenet that holds that there is a direct and positive correlation between education leading to awareness and enhanced task performance. Isn't that why we're here, kids? Incidentally, the same fellow who says you can ignore the technical side also names three criteria he considers valid in lens choice. Inside those criteria we find, you guessed it: aberrations, contrast, distortion, brightness, etc. I guess he chickened out.

LENS FUNCTION/CHARACTERISTICS

So we're going to look at aspects of lenses in terms of their "specs": focal length and speed (brightness). We'll look at performance: sharpness or resolving power, aberrations and distortion, contrast and color correction, and common phenomena like vignetting. Last, we'll discuss simply their type, from standard primes to high-speed zooms. And in explaining a telephoto, we may have to get into "node of emission."

Focal length is the distance from the approximate center of the lens (or node of emission) at which parallel rays from a point source at infinity will be focused to a point. It is also the shortest distance between the lens and the film plane at which a lens can produce a sharp image.

Node of Emission

There it is, already showing up. It is, in theory, the point where light rays exit the lens. The node of emission is located just behind the center (principal point) of the lens. The nodal plane (rear) of a compound lens is the position at which a simple lens of focal length equal to the compound lens must be located to produce equivalent focus. Both nodal point and nodal plane are optical constructs. In a telephoto lens or retrofocus wide-angle lens, the node can be located outside the lens. The adjustment of the location of the nodal point or nodal plane is accomplished by utilizing negative or positive lens elements in the system. It is done to accommodate overly large or small back-focus requirements that are dictated by long- and short-focal-length systems (telephoto and retrofocus wide-angle lens systems). (See General Lens Survey and Related Characteristics.)

Speed and Brightness

Brightness of an image is a function of the speed of the lens. The speed, relative aperture, and maximum aperture are expressed in f-stops and T-stops. The f-stops represent a mathematical ratio. T-stops represent a physical quantification of the actual amount of light transmitted by a lens. The speed of a lens is equal to the ratio of the diameter of the lens to its focal length. Represented by S, speed is equal to diameter over focal length: $S = d/f$.

Brightness is proportional to lens speed. Hence, $(s)^2 = (d/f)^2$. Lens speed is dependent on the amount of light transmitted, which is of course proportional to the lens's area, which is proportional to the square of its diameter: $A = \pi r^2$. Now remember that doubling focal length not only doubles image height, but also doubles image width. Start with a 25mm lens and an image of 2 inches by 2 inches—that is, an image area of 4 square inches. A 50mm lens doubles both values. Our new image area at twice the focal length will be twice as high and twice as wide, or 4 by 4 inches. This yields an image area of 16 square inches. The area over which the light has to spread is four times as great, so the same amount of light will render our new image at only one-quarter the original brightness. This equals two stops. This is how a doubler takes away two stops in brightness.

The f-stop numbers relate to brightness inversely. To restate: brightness equals (diameter of lens)^2/(focal length)^2, or d^2/F^2. The f-stop number, which dictates image brightness, is the reciprocal of this value. This is to render whole numbers.

$$\text{f-stop} = \frac{1}{d/F}, \text{ or } F/d$$

But! In a lens system with internal structures like aperture plates, brightness or speed depends on the diameter of the entrance pupil rather than the actual lens diameter, which must be large enough to accommodate large openings set on aperture rings.

$S = d_e/F$,
and because f-stop = $1/s$, f-stop = F/d_e.

Entrance Pupil

This is the opening that an observer would identify as the limitation on the solid angle for rays diverging from an on-axis object point. For us the aperture stop acts as the entrance pupil. The aperture stop is physically located between the object and the lens. (By lens here we mean node of emission, an optical construct, not a physical entity.) In

this position, the aperture stop limits the solid angle of the rays coming from an object.[18]

So we see that the wider the lens aperture, the brighter the image. Also, the longer the focal length, the dimmer the image. Image brightness is proportional to the interplay of the two factors: lens diameter and focal length. This is why long-focal-length lenses have higher maximum apertures and why telextenders lose light.

Brightness varies as the square of the lens diameter over the focal length, or the inverse square of the f-stop number (which is the reciprocal). A series of f-stop numbers, or for us T-stop numbers, represents an increase in brightness of two times for each stop. So as the f-stop or T-stop numbers go down, aperture size increases exponentially. Each stop number decreases by a factor of the square root of 2. See Figure 1-10.

On the front of the lens, engraved next to its focal length, is a number referring to the lens's maximum aperture. This is an f-stop number based on mathematical dimensions, not on actual light transmission. This is why on a high-speed prime lens, we'll see f1.3, but on the aperture ring we'll see T1.4. A T-stop, based on the actual amount of light transmitted by a lens, is affected in value by the same lens characteristics that affect how much light that lens is transmitting. These characteristics determine just how fast a lens is.

T-stops are checked on a light-sensitive machine, calibrated to a standard reference value. The factors that make up the dimensions and composition of the lens that affect the light being passed (to this device) are glass type, surface coatings, separation, number of air/glass/air surfaces, internal reflectance, and internal surface quality. In macro lenses, object distance is a factor when attaining unit magnification.

Glass Type

The glass used varies widely from lens to lens and with different manufacturers. There are approximately two hundred different types of optical glass. Particular combinations of elements and therefore different types of glass may be present or absent to varying degrees according to a lens's intended function. This is because, as we remember, different types of glass have different refractivity. Glasses used in various combinations, in total, refract light in varying degrees to fit the requirements of a short-focal-length lens, or a very long-focal-length lens. A lens of the same focal length made by two different companies will employ different glass. Lenses of different focal length made by a single manufacturer will be made of different types of glass. In making lenses of different focal lengths, different combinations of elements are used, requiring different combinations of glass types, according to the lens

$$\frac{T/64}{\sqrt{2}} = \frac{T/64}{1.414} = 44$$

$$\frac{T44}{\sqrt{2}} = 32$$

$$\frac{T32}{\sqrt{2}} = 22$$

$$\frac{T22}{\sqrt{2}} = 16$$

$$\frac{T16}{\sqrt{2}} = 11$$

$$\frac{T11}{\sqrt{2}} = 8$$

$$\frac{T8}{\sqrt{2}} = 5.6$$

$$\frac{T5.6}{\sqrt{2}} = 4$$

$$\frac{T5.6}{\sqrt{2}} = 2.8$$

$$\frac{T4}{\sqrt{2}} = 2.0$$

$$\frac{T3}{\sqrt{2}} = 1.4$$

44

$\sqrt{2}$

32

$\sqrt{2}$

22

$\sqrt{2}$

16

$\sqrt{2}$

11

$\sqrt{2}$

8

$\sqrt{2}$

5.6

$\sqrt{2}$

4

$\sqrt{2}$

2.8

$\sqrt{2}$

2.0

$\sqrt{2}$

1.4

Figure 1-10.
Stop numbers are related to each other by a factor of the square root of 2.

"recipe." Also, different glasses have different absorption values. Most absorb more blue light and less red, because light at the blue end of the spectrum tends to scatter more.

Surface Coating

T-stops are also affected by the transparency of the glass itself. F-stop numbers assume a lens is perfectly transparent. This is not the case. Approximately 5 to 8 percent of the incident light is lost by reflection at each air/glass/air surface. To reduce these reflection losses, the elements are coated with a thin layer of material. The coating's refractive index is intermediate between the values of air and glass. Light rays would otherwise strike a glass/air interface at too critical an angle, or one too acute (obtuse to the normal) to the glass, and be reflected. They would never pass on to form an image. The slightly different refractivities of the coatings at an interface cause a slight change in the directional path of a ray. Now the same ray will be presented at a more obtuse (acute to the normal) angle to the glass. The ray will be transmitted through the glass/air interface and pass on to form an image. Though coatings at an interface reduce reflectance from approximately 5 percent to about 1.5 percent, they still interact with light transmission. Different types and numbers of coatings are used from lens to lens. In photographic lenses, magnesium fluoride may be used or multicoatings of different combinations are used. Again the key determinant is design.

Separation

The separation of air/glass/air surfaces is seen from the preceding paragraph to be an obvious factor. Elements close enough together can interact with light reflected off internal surfaces to make the light "carom" right back out of the system. Does stacking multiple filters come to mind here?

Multiple Surfaces

The number of air/glass/air surfaces multiplies the percentage of light loss, due to reflectance of each element at each interface. With the use of coatings, this loss is considered negligible.

Internal Surface Quality

Internal reflectance is also partly a function of the surface quality of the inside of the lens barrel. The inside surfaces should be a flat nonreflective black. The surfaces are textured to keep light from concentrating and to avoid specular reflection. The varied surface, instead sends the light diverging in many angles, rendering stray light more diffuse and less of a factor.

Finally, object distance is a factor affecting the amount of light reaching the image surface in a macro lens. Unit magnification is a one to one object size to image size ratio. This is the same ratio as object distance to image distance in a lens. Let's look at the lens equation:

$1/f = 1/u + 1/v.$
f = focal length
u = object distance
v = image distance
So at unit magnification: $u = v$, and $1/f = 1/u + 1/v$
And if $u = v$, then $1/f = 2/u$.
And $u = 2f$

So at unit magnification, both object and image will be twice the focal length from the lens. From earlier discussion we remember that as focal length is doubled, image area is squared.

Original image area = $A = H \times W$
Double focal length = $(2 \times H) \times (2 \times W) = 2^2A$

And with the image covering four times the original area, the brightness will be one-quarter of its original value. Let's use a hypothetical lens with a diameter of 1 and a focal length of 2. Remember

$S = d_e/f$
$d_e = 1$
$F = 2$
And $(d_e)2/(F)^2 = 1^2/2^2 = 1/4$

Doubling the focal length (unit magnification) gives us

$(d_e)^2/(2F)^2 = (1)^2/(4)^2 = 1/16$

This is one-quarter of one-quarter, which is the case in unit magnification in a macro lens.

So now you know the simple optical mechanics of lens function. And you understand a bit about the characteristics of a lens. These are focal length (image size) and speed (image brightness). But that is a perfect lens and this is not a perfect world. Next we will look at the performance variables that interact with the above characteristics of a lens.

The primary variable in lens performance is sharpness. Sharpness is a function of the resolving power of a lens. The resolution of film you

can blame on Kodak, Fuji, or Agfa. Sharpness is also a function of contrast of a lens and color correction. They are related to the use of coatings and the degree of aberrational correction. The "fully corrected" lens is not fully corrected. Sharpness is also judged by certain subjective human factors.

So it sounds like the caterer is bringing a good lunch, (ho hum, same old stuff) and you want to still be here after lunch, when the big dogs have looked at yesterday's dailies. You've finished dessert, you've made all your calls; still no sign of the guys with the big beany copters. Suddenly, they emerge from the screening. You try to read those sour faces. Is it indigestion or is it you they're thinking about? You have that slightly out of control feeling. Well, you tried your best and probably did a good job. It must be the tarragon chicken. White meat's a favorite food of movie people in the nineties.

But you want to feel sure of your focus. So to help ensure your precious focus, the exec's precious and very expensive footage, as well as a few careers and egos, you want to start with the best equipment, that is, the sharpest lenses. The following is a discussion of how lenses are able to be as sharp as they are.

Technically, one way to judge sharpness is to look at resolving power. This is a judgment of an aerial image. An aerial image is one formed in space (air). The real image (image formed on physical material) on the film is a function of the resolving power of the lens and the resolution of the film.

LENS → RESOLVING POWER → AERIAL IMAGE → FILM → RESOLUTION → REAL IMAGE

Let's focus on the lens (heh heh ... small pun). One way resolving power is rated is by the number of lines per millimeter that can be distinguished or "resolved" by a lens. Optical resolving power is indicated by spatial frequency (unit mm^{-1}). But this is only part of the story.

Resolving power is limited by contrast of test charts, as well as aperture, wavelength, object distance, and subjective factors. Black and white lines don't necessarily give the sharpest results. Test objects, where contrast varies according to a sine function, will give different results. The number of lines distinguished by a lens, its resolving power, may be the same at two different apertures, but the contrast (apparent sharpness), due to aberration/diffraction limitations of the lens, may be quite different. So there is, more correctly, no one resolving power of a lens, so much as there is "RP" at different conditions of the lens and object.

In the real world, movies are made in color. They're not black-and-white test charts. In addition to monochromatic aberration effects, the ability to focus simultaneously different colors, or wavelengths of light, is related to lateral and longitudinal chromatic aberrations. There are equations that indicate resolving power to increase with reduced wavelength and increased f-stop numbers. Practical use with a real lens shows stopping down to increase lens performance. This is only to a point, where diffraction effects take over. (Heh heh, later, kids.) This does imply that a lens has an optimum aperture range, which is usually between maximum and minimum aperture values by two to three stops. At smaller apertures, resolving power is affected by aperture shape, due to diffraction effects and because of aberration correction, which is greater in the center of a lens, compared to its edges. The "RP" varies greatly when measured in these different areas. This is especially true at larger apertures.

So when you talk about "RP," you're talking about a lot of variables, none of which can be made perfect. If it's any consolation, 35mm camera lenses have twice the resolving power of lenses for use with larger camera formats. Lenses intended for use with 35mm cameras are designed to stand up to higher standards. This is due to the ultimate magnification that is required of the images they transmit.

And we haven't even gotten to the film with our image yet. A camera is a marriage of optical, mechanical, and chemical systems. First, there are problems of vignetting and even camera shake, before you even deal with the relative flatness or unflatness of the film. Cost restrictions limit types of optical glass used as well as other design factors, such as aspheric surfaces and floating elements. They all affect performance of a design. And there are human factors.

Holy toot!

Human factors are psychological and subjective. One's "impression" of a lens's sharpness is a function of its contrast. A lens can rate number-wise the same number of lines resolved, from one instance to another, yet a human will judge one image sharper than another. We discussed the manipulation of aberrational interaction by changing the aperture, but before we finish with the technical side of sharpness, let's look a bit more at contrast. Simply, contrast means flare and fog introduced by the characteristics of a lens. We saw that aberration contributes to the effect of decreased contrast. Contrast is affected not only by size and shape of the aperture, but also position of the aperture. For many reasons, a technician may sometimes alter the position of a diaphragm from its original position in a lens's design. Seeing as how every surface reflects to some degree, this new position of an existing surface bounces light in directions not originally taken into considera-

tion. You know that separation is a factor in light transmission. It is obvious how changing the longitudinal position of a diaphragm and its surfaces changes the separation of a lens. (Look how smart you're getting.)

So why do people monkey with lenses? To make them function better. A simple lens will not render anything near the corrected image yielded by complex lens "recipes" (combinations) that are tested on a computer before a lens actually exists in the world (cosmos). What are the computer-designed lenses corrected for?

ABERRATION

There are five kinds of monochromatic aberrations, two kinds of distortion, and primary chromatic aberration. But what is aberration and its seven ugly sisters? First a word from sleeping beauty.

The perfect lens is aberration free. It is a diffraction-limited lens. All rays from an object point converge on an image point. An orthogonal object plane's image is an orthogonal plane (see Chapter Four, "Terms and Definitions"). Object and image shapes are identical proportionately. A perfect lens emits from its exit pupil (the final interactive limiting component of a lens) a spherical wavefront, which converges to an image point. The actual emergent wavefront is not evenly spherical—it's ridged or crinkly. Instead of an image point, it yields an image patch.

Aberrations come from the qualities inherent in spherical surfaces. This is because refraction varies across the annular zones of a lens surface. These banded zones are concentric. Monochromatic anomalies are also called Von Seidel aberrations. They are spherical aberration, coma, astigmatism, curvature of field, and distortion. Spherical aberration affects the entire image from axis to periphery. The others interact positively with contingencies of field angle to the degree off-axis. Increasing these factors increases the degree of aberration. There are two kinds of chromatic aberration as well: lateral chromatic aberration and longitudinal chromatic aberration. Their effect is the differential focusing of different wavelengths (colors) of light.

Aberrations are dependent on curvature, thickness, refractive index, separation, and aperture position. Lenses for motion-picture photography come from different groups or designs, according to different intended purposes: primes, zooms, wide angles, and telephotos. They address low light, versatility, coverage, and power, respectively. Because of this, different lenses have different weak points and strong

points to be aware of. We'll look at this when we consider lens types. But all aberrations are always present to some degree. What are they?

Spherical Aberration (SA)

Spherical aberration is a condition of a lens that does not give stigmatic imagery. In *Webster's Third New International Dictionary:* Stigmatic—4: anastigmatic—used especially of light rays intersecting at a single point.[19] With spherical aberration, light rays do not all focus at a single point.

As SA affects the entire image, it follows that SA ($W_{040}r^4$) depends on the zone of the pupil, and not on azimuth or field angle (incident ray angle). From this it follows that longitudinal spherical aberration (LSA) and transverse spherical aberration (TSA) will be seen. See Figure 1-11.

The principal effect is that marginal rays will be brought into closer focus than will paraxial rays. The refractivity near the edge of a spherical lens is greater and so it affects marginal rays to a greater ex-

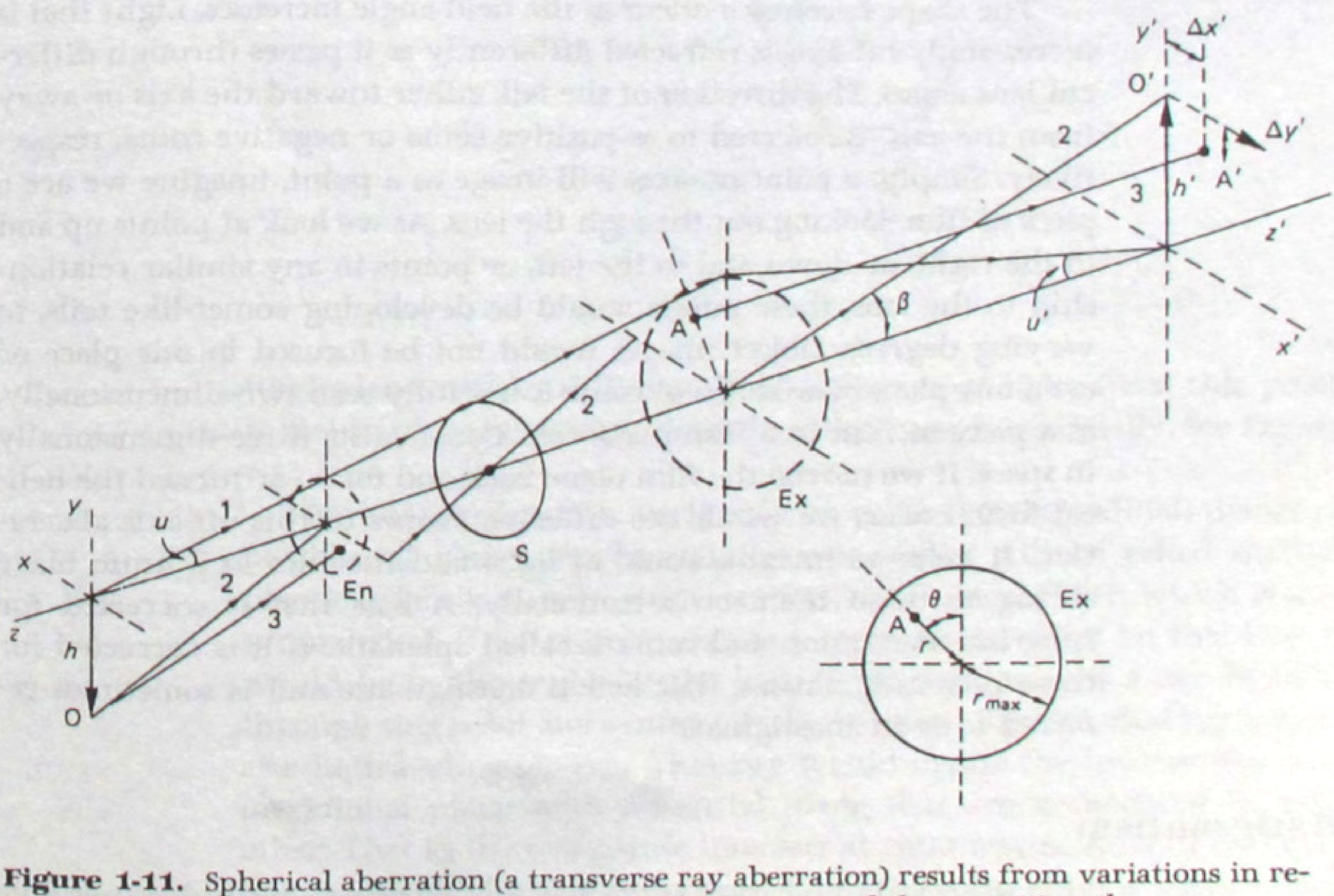


Figure 1-11. Spherical aberration (a transverse ray aberration) results from variations in refractivity by different annular zones of a len's chief ray (2) and skewray (3) as they pass through different zones. Their images are displaced horizontally and vertically by Δx' and Δy'.

tent. A zone including differing focal points of paraxial and marginal rays takes on length and width. The zone is called a "caustic." Instead of a position of focus, there is a zone of best focus. It depends on how stopped down the lens is. Remember, as we close the diaphragm, we constrict the entrance/exit pupil of the lens, restricting those pesky marginal rays.

In design, a lens can be made to deviate incident light rays by equal amounts at each refracting surface. The combination of two elements of equal, but opposite, spherical aberration almost completely cancels out the defect.

Coma

Like SA, coma does not give stigmatic imagery. Unlike SA, coma does not affect the entire image. Coma interacts positively with degree of field angle of incident rays. Considered the most troublesome aberration, it is the failure of each annular zone of a lens to give identical magnification. Its asymmetrical effect and its own asymmetrical image give it its name, which comes from the Latin word for comet. See Figure 1-12.

The shape becomes evident as the field angle increases. Light that is increasingly off-axis is refracted differently as it passes through different lens zones. The direction of the tail, either toward the axis or away from the axis, is referred to as positive coma or negative coma, respectively. Simply, a point on-axis will image as a point. Imagine we are a piece of film, looking out through the lens. As we look at points up and to the right, or down and to the left, or points in any similar relationship to the lens, these points would be developing comet-like tails, to varying degrees. Object images would not be focused in one place or even one plane. The shape of coma is not fully seen two-dimensionally, as a piece of film in a film plane sees. Coma exists three-dimensionally in space. If we moved the film plane back and forth, or turned the helical focus collar, we would see differing shapes of this off-axis aberration. It helps to imagine cones of light and the film as a knife blade slicing through them cross-sectionally. A lens that is corrected for spherical aberration and coma is called aplanatic. If it is corrected for these plus astigmatism, that lens is anastigmatic and is sometimes referred to as an anastigmat.

Astigmatism

Like spherical aberration and coma, and like its name, it does not give stigmatic imagery. Astigmatism is the failure of all points of an object to focus in the same image plane. The location of an object point's image

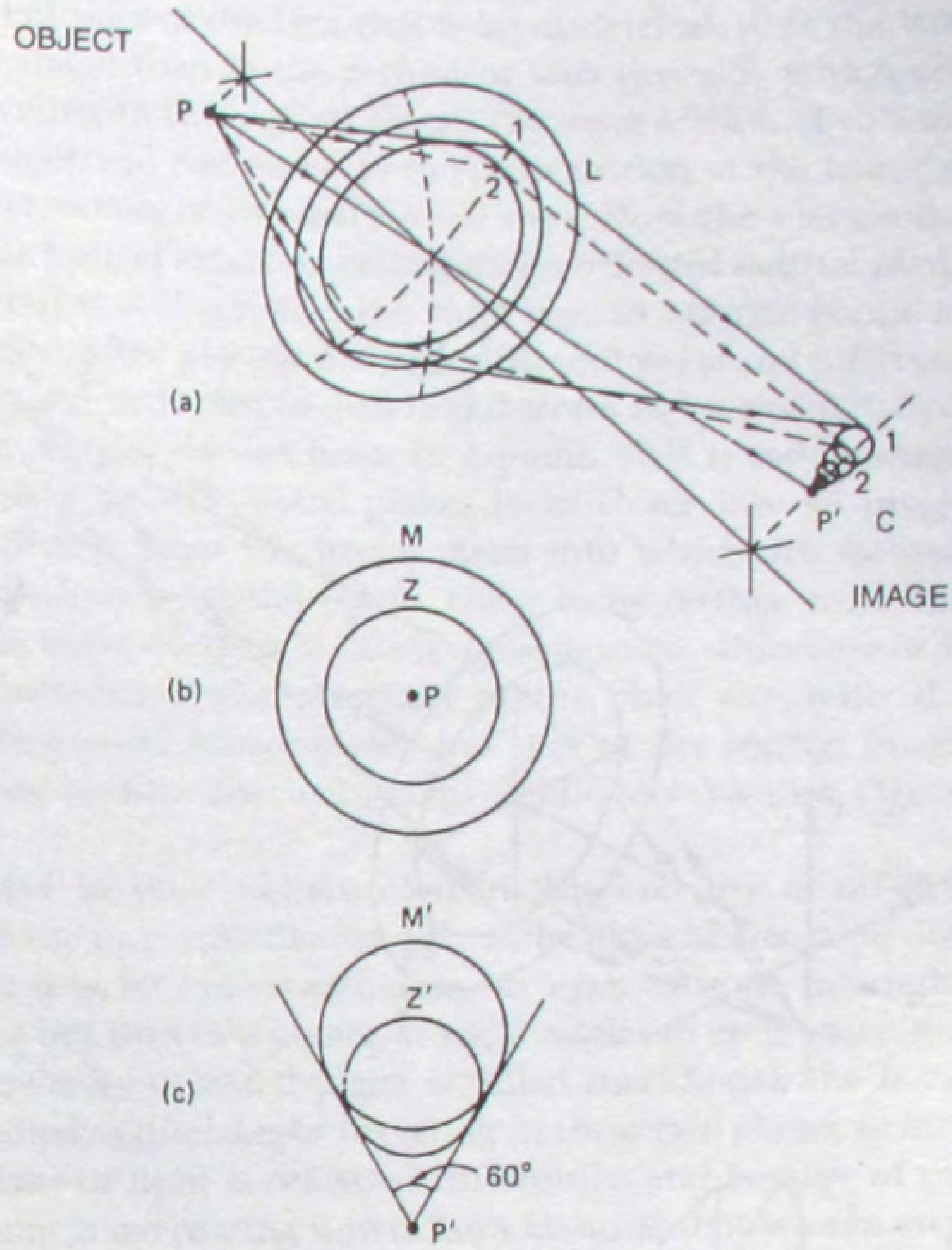


Figure 1-12.
(a) Geometry of the formation of coma. (b) Paraxial, zonal, and marginal regions of a lens. (c) The three regions' contribution to coma.

focal plane will be different if off-axis rays of light from this point travel in planes that are oriented vertically or horizontally. See Figure 1-13.

For this explanation, we'll refer to vertical (longitudinal) planes as meridional planes. Horizontal (lateral) planes will be called sagittal planes. A lens is a symmetrical section, cut from a sphere, which is also symmetrical. If we were to choose a symmetrical point on this lens, it would be in the center of the lens. If we were to pass a ray of light through this point and symmetrically through the lens, that ray would also be traveling on-axis. That ray would define the intersection of a meridional plane with a sagittal plane that are orthogonal to each other. That is, the two planes intersect at right angles. Now, if we were to imagine the sliced cross section of lens that each on-axis plane makes at its intersection with the lens, we would see two symmetrical cross sections of the lens. Each plane contains the optical axis of the lens. Each

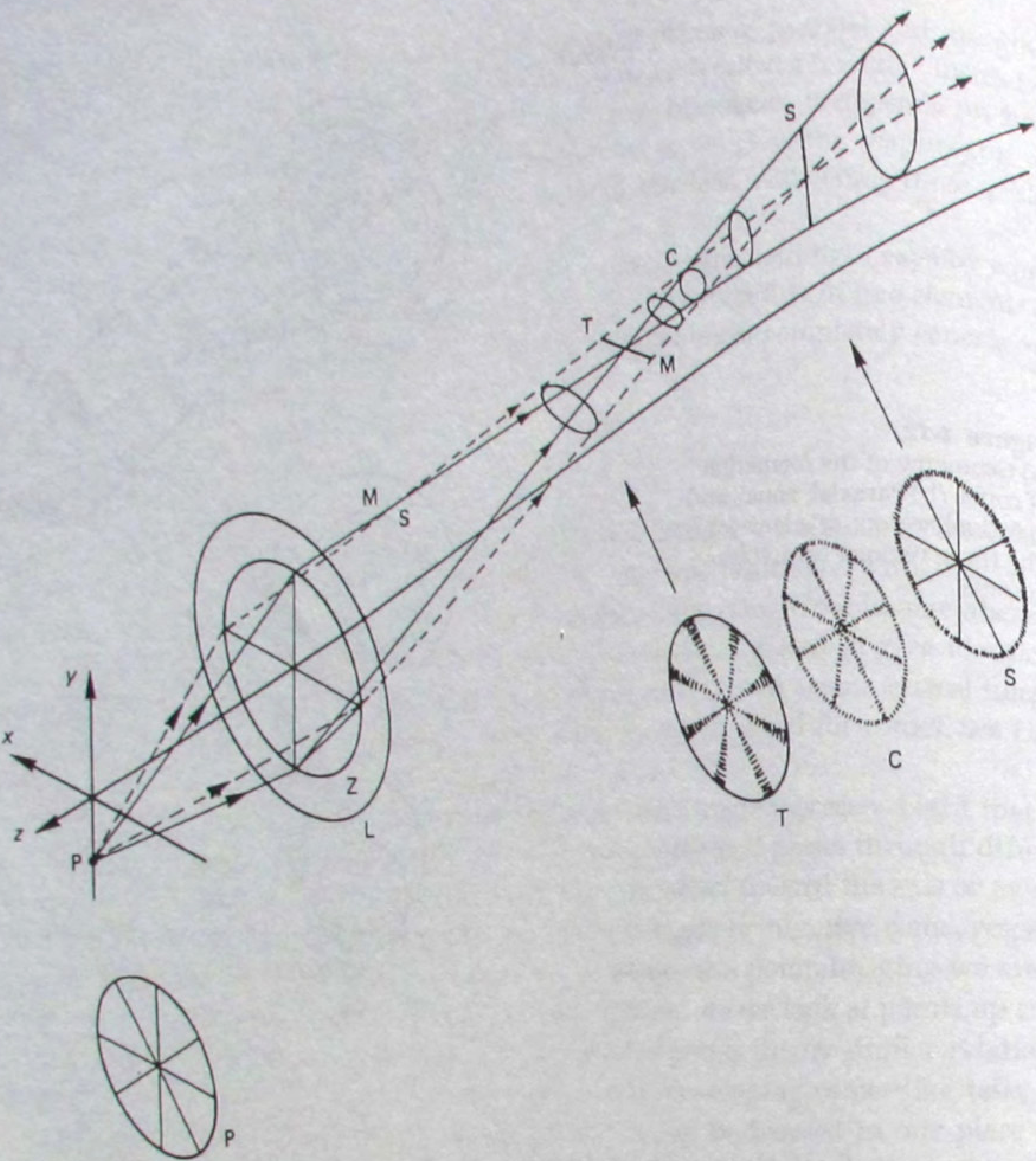


Figure 1-13. Rays traveling in meridional (tangential) and sagittal planes encounter different "shapes" of the lens and are refracted to different degrees. The appearance of a spoked wheel subject (P), imaged at the sagittal (S), circle of least confusion (C), and tangential (T) foci.

contains the chief ray, which is the central ray of a bundle of light, emanating from a point. The object points, whose rays travel in each of the two planes, will focus in the same image plane, because they encounter like sections of the lens. They are refracted identically, appropriately, accordingly, and respectively (phew!). Now, let's choose a point off-axis. This is where the problems arise.

Let's take a point from the top of an object. These rays in the meridional plane are now traveling at an angle, and are thus passing

through a different part of the lens that is asymmetrical. Here the lens is of a different shape than is the section of lens through which are passing rays traveling in the sagittal plane. The cross section of this intersection is symmetrical compared to the cross section of the lens, defined by the intersection of the meridional rays. Now the meridional plane contains the optical axis. The orthogonally oriented sagittal plane no longer does, but it still contains the chief ray. So off-axis points of light from an object, after passing through different parts and different shapes of the lens, are refracted to different degrees and focus in different planes. Their images do not focus in a point. This is astigmatism. Light rays traveling in meridional planes focus closer into an image plane that is different from the image plane into which are focused light rays traveling in a sagittal plane. These focus farther from the lens. The distance between these is called the astigmatic difference. It is the difference between the intersection of the chief ray with the meridional, or tangential, image plane, and that of the sagittal image plane. It increases rapidly for increasingly oblique rays. (See Figure 1-15a.)

To further aid in your visualization of this inability of off-axis light rays, traveling in perpendicular planes, to focus at the same distance behind the lens, let's relax and close our eyes. Imagine that light from a point fans out into two planes, at right angles to each other. Remember, the vertically oriented plane is called meridional; the horizontal plane is called sagittal. Light traveling in these two planes strikes the lens. Each plane of light is refracted differently, and because of refraction each plane is narrowing down. Let's imagine that we can step inside the lens. The edges of each plane are getting closer to each other. But they are focusing and narrowing at different rates, due to differential degrees of refraction. The meridional plane will focus into a point before the sagittal plane narrows into a point. The meridional, or tangential, plane is focusing down faster. The convergence of the triangular-shaped sections of planes would first describe an ellipse. This would be an oval lying on its side. It's on its side because its major, or longer, axis is the horizontal axis. This is because the horizontal sagittal plane is focusing down to a point at a slower rate. The focusing sagittal plane's edges are still farther apart than are those of the vertical meridional plane. Remember the distances between the respective planes' edges are the lengths of the two axes of the ellipse. In our mind, we move farther down along the focusing path of the two planes. It's kind of cool in here, isn't it? And look at how clean everything is. In front of us... Bam! The door slams shut. The faster, closer focusing meridional plane has focused. The length of the vertical axis is zero. The sagittal plane has not focused yet. It still has width. The horizontal

axis still has length greater than zero. The image behind the lens, which has no height, only width, is a two-dimensional line. This line that we see in front of us is the sagittal image plane. Let's step over it and keep going. Rays of the meridional plane have crossed at their focus and are diverging again. The vertical axis is growing again as the horizontal sagittal plane continues focusing down. As its vertical axis grows, the shrinking horizontal axis reaches a point where its length is equal to the vertical axis, forming a circle. This is the circle of least confusion. It exists in the zone of best focus in the astigmatic lens. Let's keep going. As the meridional plane is now still widening, the sagittal plane is still narrowing. The vertical axis is now longer than the horizontal axis. We see an ellipse with its major axis in the vertical plane. The walls on our sides are closing in, and up ahead there is a vertical line at the point where the sagittal plane has focused in its image plane. The diverging meridional plane has gained some length in a vertical direction. From here the rays continue on to infinity. I forgot to tell you there was no camera at the back of the lens.

There's a test for astigmatism, but first let's go for a bike ride. Before we go, let's take a picture of the bike's front wheel. (See Figure 1-13 and Figure 1-14.) Uh oh, it looks like your camera has an astigmatic lens. The rim appears sharp, but the spokes are out of focus. Let's refocus the lens and take another picture. Now the spokes are sharp, but the rim is out of focus. If we try a middle focus, we find we can never get true focus on spokes and rim at the same time. The spokes and the rim are at right angles to each other, and the light rays emanating from them travel in planes that are at right angles to each other. The meridional and sagittal planes and the rays traveling in these orthogonally oriented planes encounter different shapes of the lens. The light is refracted to differing degrees and focuses in different places. If the film plane of our camera is moved to the closer focus, at our horizontal line, we see focus at the tangential plane. The rim is in focus. As we move our film back to our circle, rim focus is degraded and spoke focus improves, but both are soft. As we move the film back to the farther focus, where the vertical line is, we see focus at the sagittal image plane. The spokes are in focus. You're now an expert on astigmatism. No one except an optical engineer understands it better than you. Let's get out of here. (See Figure 1-13.)

Oh, no. There's more? Just a little bit. We're near the end of the most technical chapter, which is the most technical part of the book. So it's just going to get easier from here, and you'll be able to answer questions with real answers. You'll be able to understand part of your job on a theoretical basis, rather than just doing it by rote, like a monkey. Do surgeons operate because they know it cures patients, "just because," without understanding why it works? Sometimes, yes.

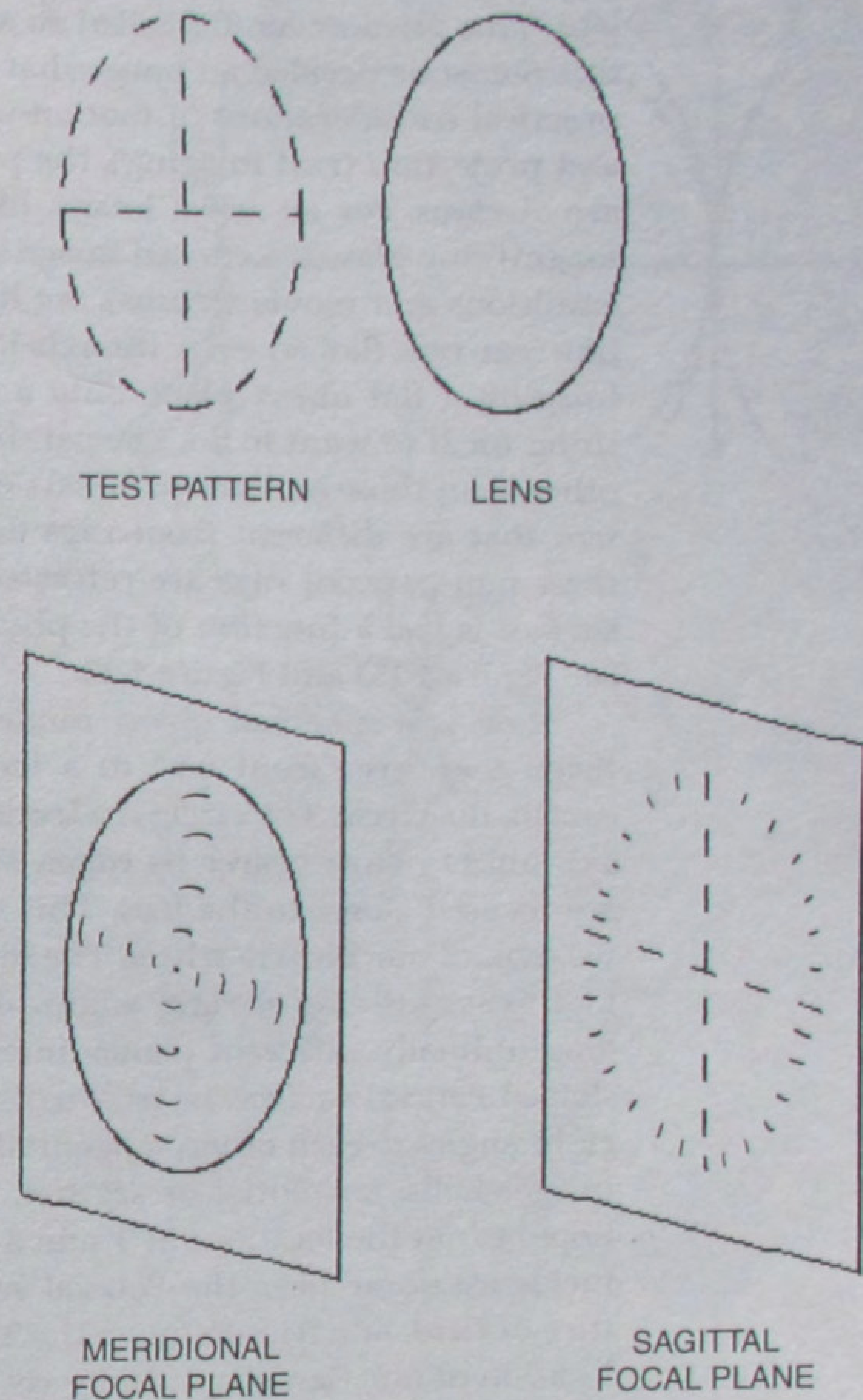


Figure 1-14.
Test for astigmatism.

Curvature of Field (COF)

A lens can be corrected for spherical aberration, coma, and astigmatism and yield stigmatic imagery, but it will tend to want to focus these nice clean images onto a curved field. Image fields are rendered as image shells that are paraboloid in shape. The shell is called a Petzval surface. It only approximates being planar for an on-axis ray. This is a ray traveling from the central point of an object, or from infinity, and imaging centrally in the focal plane.

The shape of a Petzval surface, in a positive (converging) lens, which is what we use, is like a dish with its edges dishing toward the

lens. This phenomenon is called an aberration, in that it is an image defect. Someone decided an image that is not flat is defective. Well, for the practical considerations of motion-picture photography (real imaging) and projection (real imaging), the problems of a curved image surface are obvious. For an aerial image, like that produced by binoculars or magnifying glasses, a curved image is fine. But for "real" images (photo-emulsions and movie screens), we like 'em flat. You could say that we like 'em real flat! So even though it's considered an aberration, a lens imaging a flat object plane onto a curved surface is a fairly natural thing for it to want to do. The parabolic shape is just a function of rays, other than those on-axis (paraxial), encountering shapes of the lens system that are different from rays dead on-axis. And like astigmatism, these non-paraxial rays are refracted to different degrees. The Petzval surface is just a function of the physical/optical mechanics of the lens. See Figure 1-15a and Figure 1-16.

How is a spherical object rendered? It too is imaged in a curved field. A sphere "front on," to a lens, appears as its two-dimensional cousin, the circle. The circle is a section of a plane with increasingly off-axis object points nearer its edges. More distally located points off-axis are focused closer to the lens. This sounds like the astigmatic pictures we took of our bicycle wheel. The difference is that COF is symmetrical. Light rays off-axis, at right angles, or not, to each other, are focused in longitudinally different planar intersections of the same parabolically shaped Petzval surface. In astigmatism, light rays traveling in planes at right angles to each other, tangential or sagittal, are focused in different image shells, tangential or sagittal. In correcting for astigmatism, one hopes to get the locations of T and S shells to coincide and have that coincidence occur near the Petzval surface. Then, correcting for curvature of field, one tries to move the T, S, and Petzval surfaces near to the location of our Gaussian (ideally really flat) image plane.

Lenses are thus corrected by applying appropriately negatively or positively shaped lenses to the lens system. Most often plano-convex field flatteners are applied to positive converging lens systems, near the focal plane. (See Figure 1-15b and Figure 1-17.) This causes one of our image shells to reverse its direction, intersecting the other two. This produces a "usefully" flat image surface (net focal length) that is big enough around to produce a photographable image at the focal plane. Flatteners (negative diverging lenses) are added to a positive lens system, alleviating curvature of field. (See Figure 1-15c.)

COF can occur when a lens is focused close. A macro lens is an example of this. Curvature in a lens like this increases with magnification. The curvature is a function of Y in this equation for the diameter of circle of least confusion (best focus) $D = Y^2/3FN$. Y, being the vertical

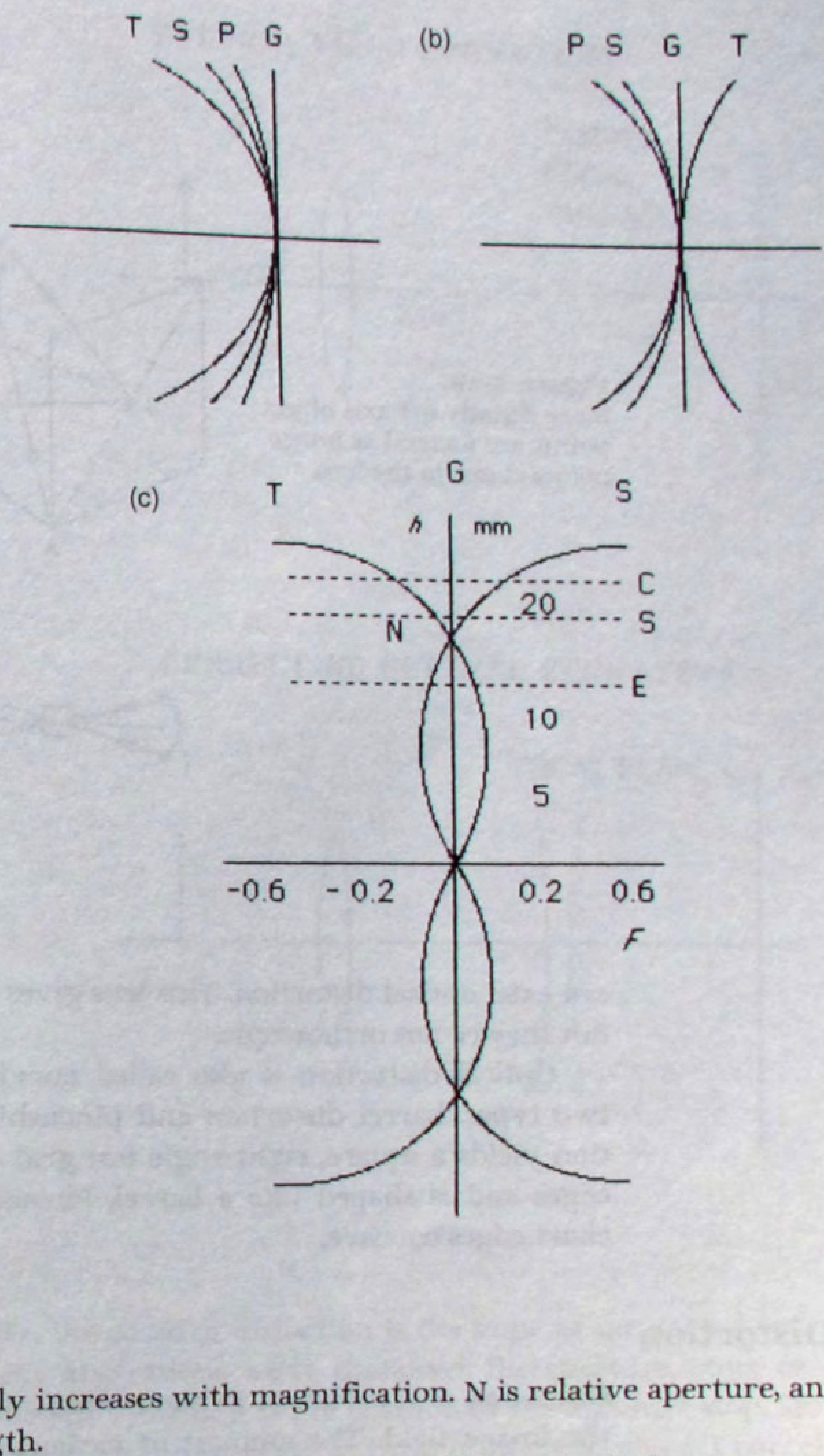


Figure 1-15a, b, c. Astigmatism and curvature of field.
(a) Image surfaces:
T = tangential surface
S = sagittal surface
P = Petzval surface
G = Gaussian image plane
(b) Manipulation of S and T surfaces to give a flatter field.
(c) Astigmatism correction yielding a net image plane.

axis, obviously increases with magnification. N is relative aperture, and f is focal length.

So what? Maybe at your next prep, you'll sound a little more competent when you detect minor off-axis focus shifts. Hah! Maybe they'll dig you up a more corrected lens. If not, stop down. And maybe you'll appreciate the need to be a little tougher in your lens checks when you're working for the DP who likes to shoot at four foot-candles. Can't stop down then, can you?

In a lens corrected for SA, coma, astigmatism, and COF, there still

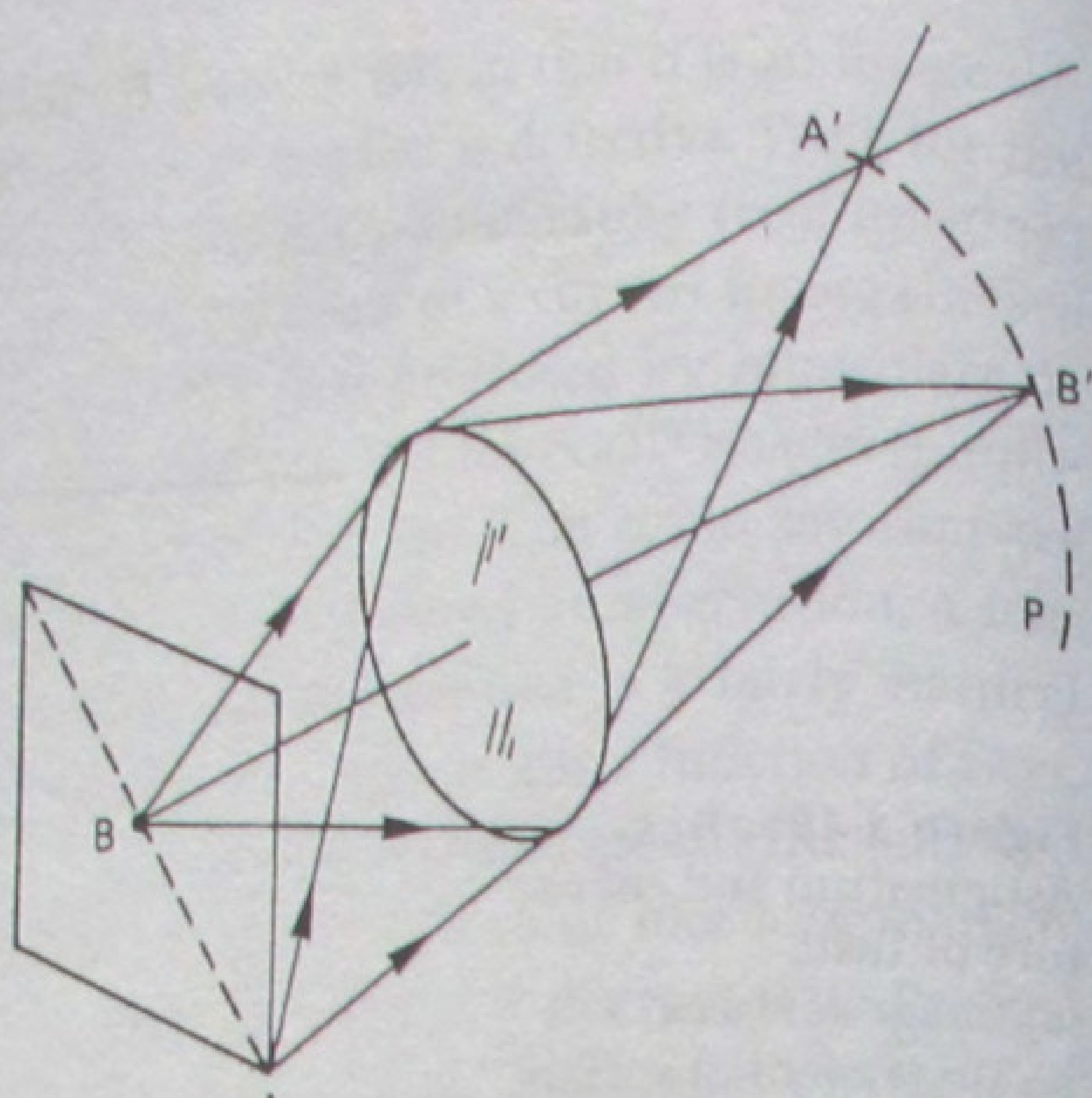
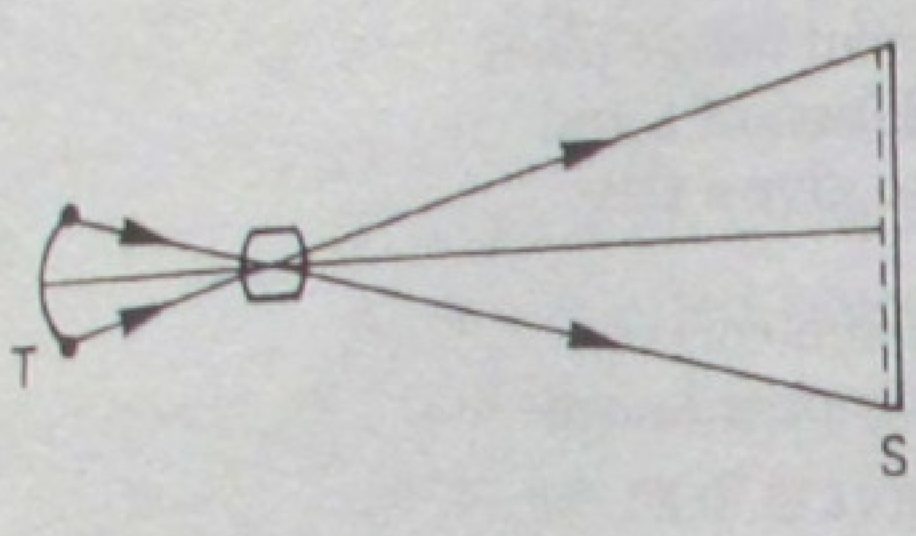


Figure 1-16.
More distally off-axis object points are focused as image points closer to the lens.



can exist optical distortion. This lens gives stigmatic and planar images. But they're not orthoscopic.

Optical distortion is also called curvilinear distortion. There are two types: barrel distortion and pincushion distortion. Barrel distortion yields a square, right-angle test grid as an image that has convex edges and is shaped like a barrel. Pincushion distortion renders test chart edges concave.

Distortion

Distortion is a variation in the linear/transverse magnification across the image field. The amount of variance in magnification is a cubic function of the image height, or radial distance from the axis. The exponential effect is seen in the accelerating and decelerating shape of the curves of the edges, as it affects a test grid. See Figure 1-18. (Hey, kid... Exponential/logarithmic: graph an exponent and the line will curve. Psst... Accelerate/decelerate: an increasing or decreasing rate of change occurring over time, or distance, or both.) Some people say it's all the same, anyway. But hey! It's all relative, right?

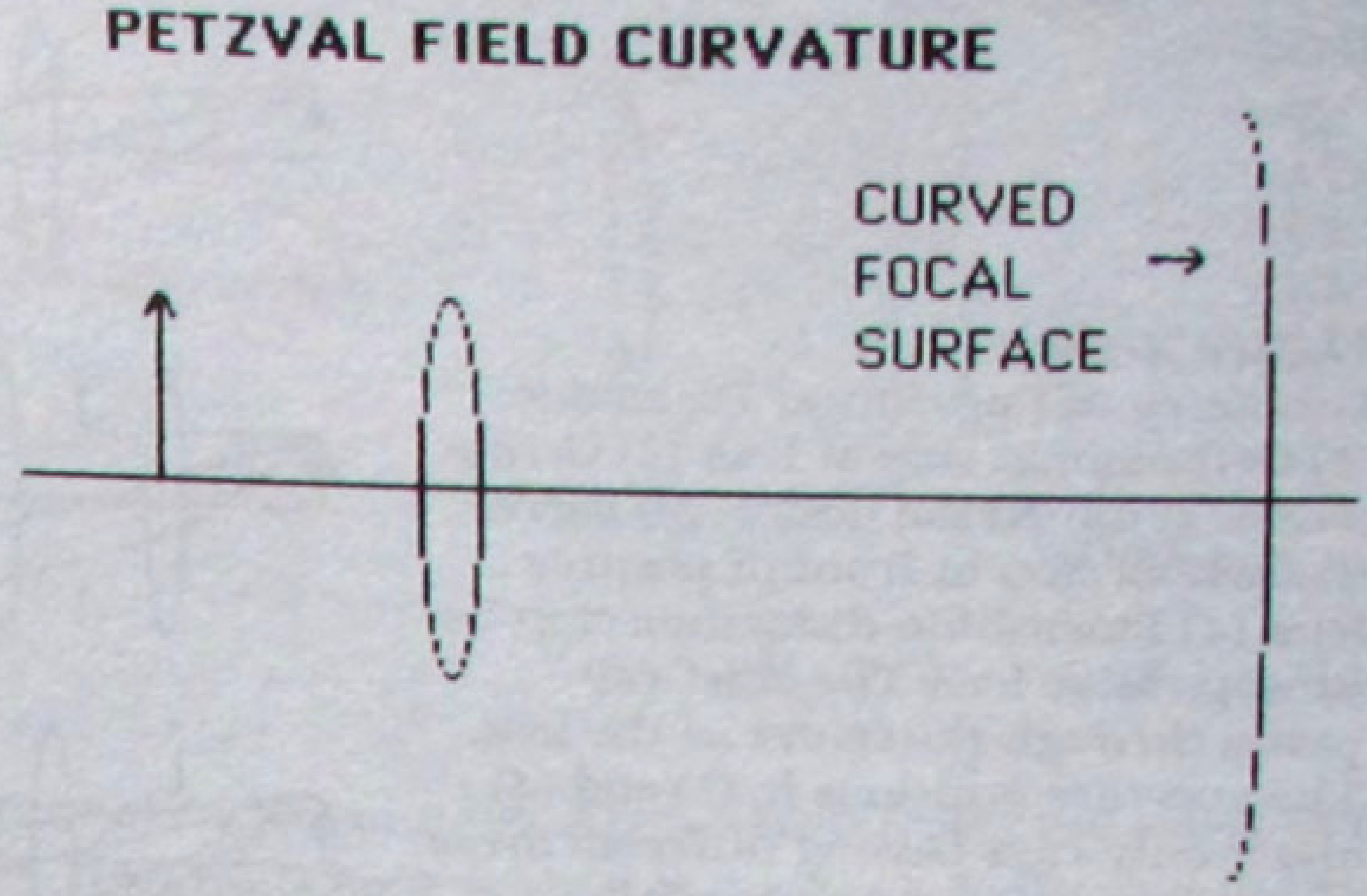
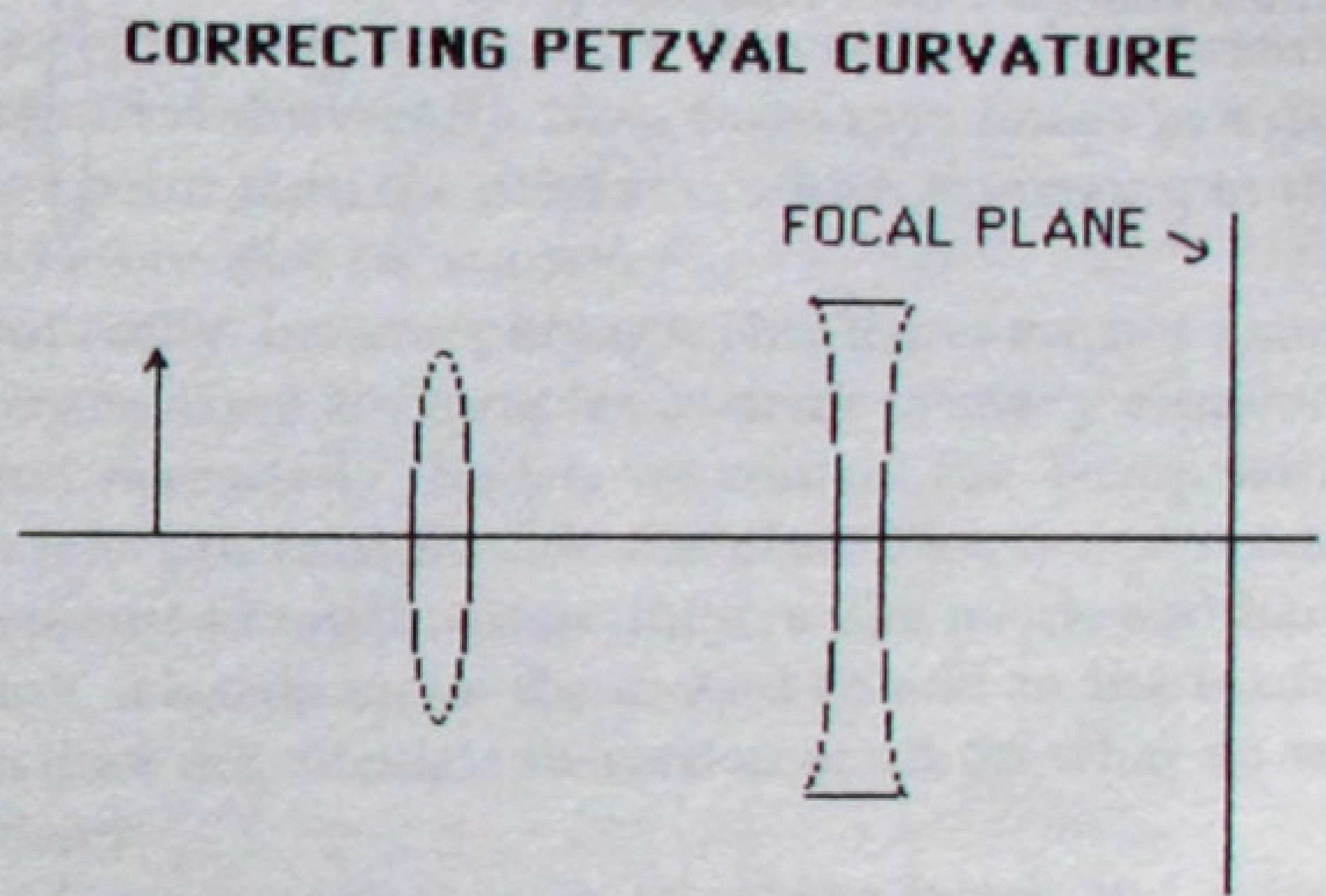


Figure 1-17.
Field.



Interestingly, the cause of distortion is the same as the partial cure for the foregoing aberrations we've discussed: the aperture. More exactly, in a simple lens system, it is the position of the aperture stop. See Figure 1-18. If you place the aperture in front of the lens, you get barrel distortion. If you place the aperture behind the lens, you get pincushion distortion.

The reason has to do with where light rays are allowed to travel by the aperture. In a lens with an aperture right at its surface, or no aperture at all, the chief ray is allowed to pass through the optical center of the lens. It is refracted, though essentially not deviated. It continues on to image at the proper Gaussian point in the image plane, as do all the

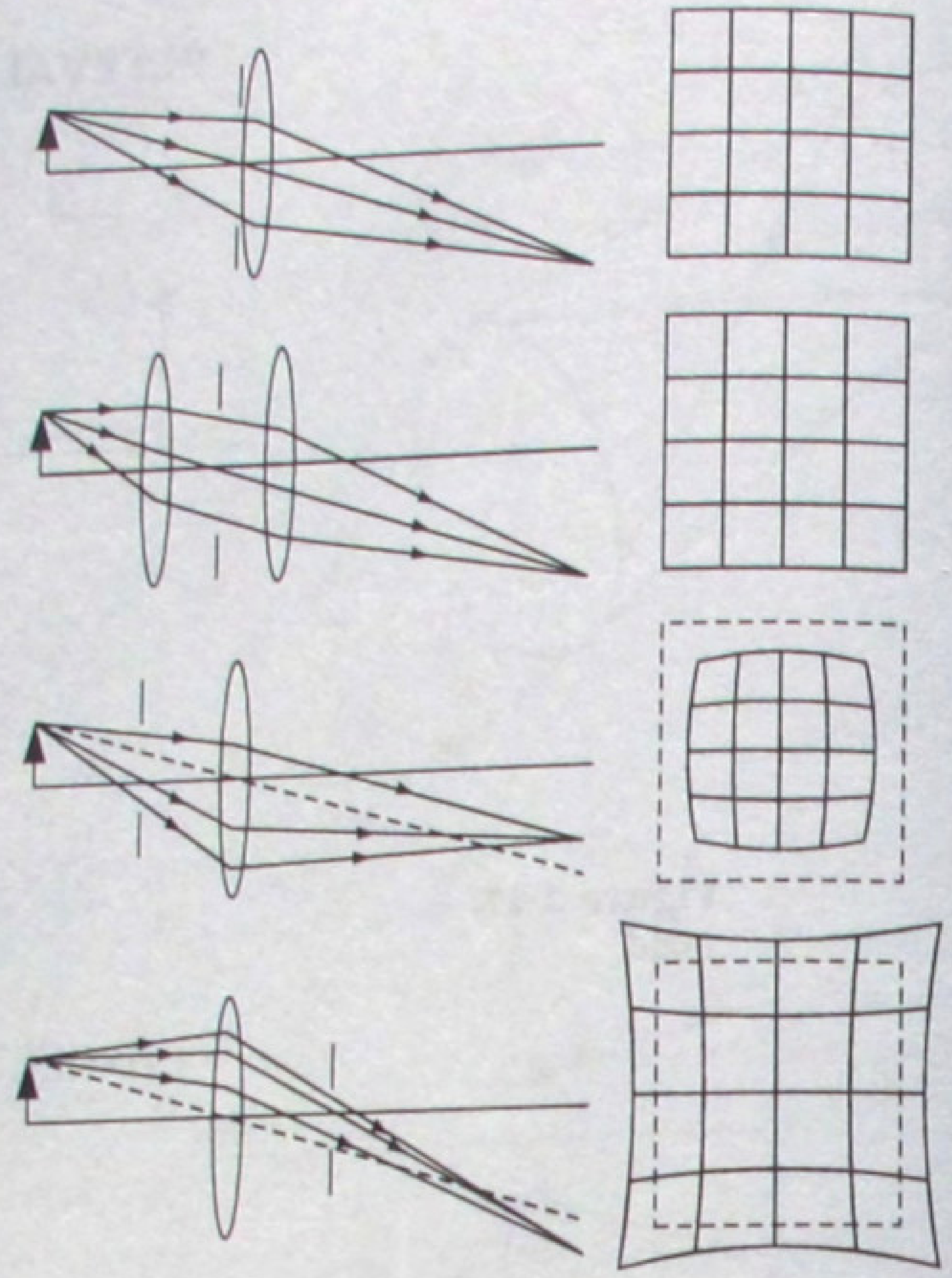


Figure 1-18a.
Geometry of Curvilinear Distortion: (1) Orthoscopic: stop at lens. (2) Orthoscopic: symmetrical design. (3) Barrel distortion: stop in front of positive lens. (4) Pincushion distortion: stop behind positive lens. The chief ray passes through the center of the lens. The aperture positions in (3) and (4) allow only rays passing different areas of the lens causing distortion. Reprinted from Sidney F. Ray, *Applied Photographic Optics: Imaging Systems for Photography, Film and Video.* London: Focal Press, 1988, p. 78.

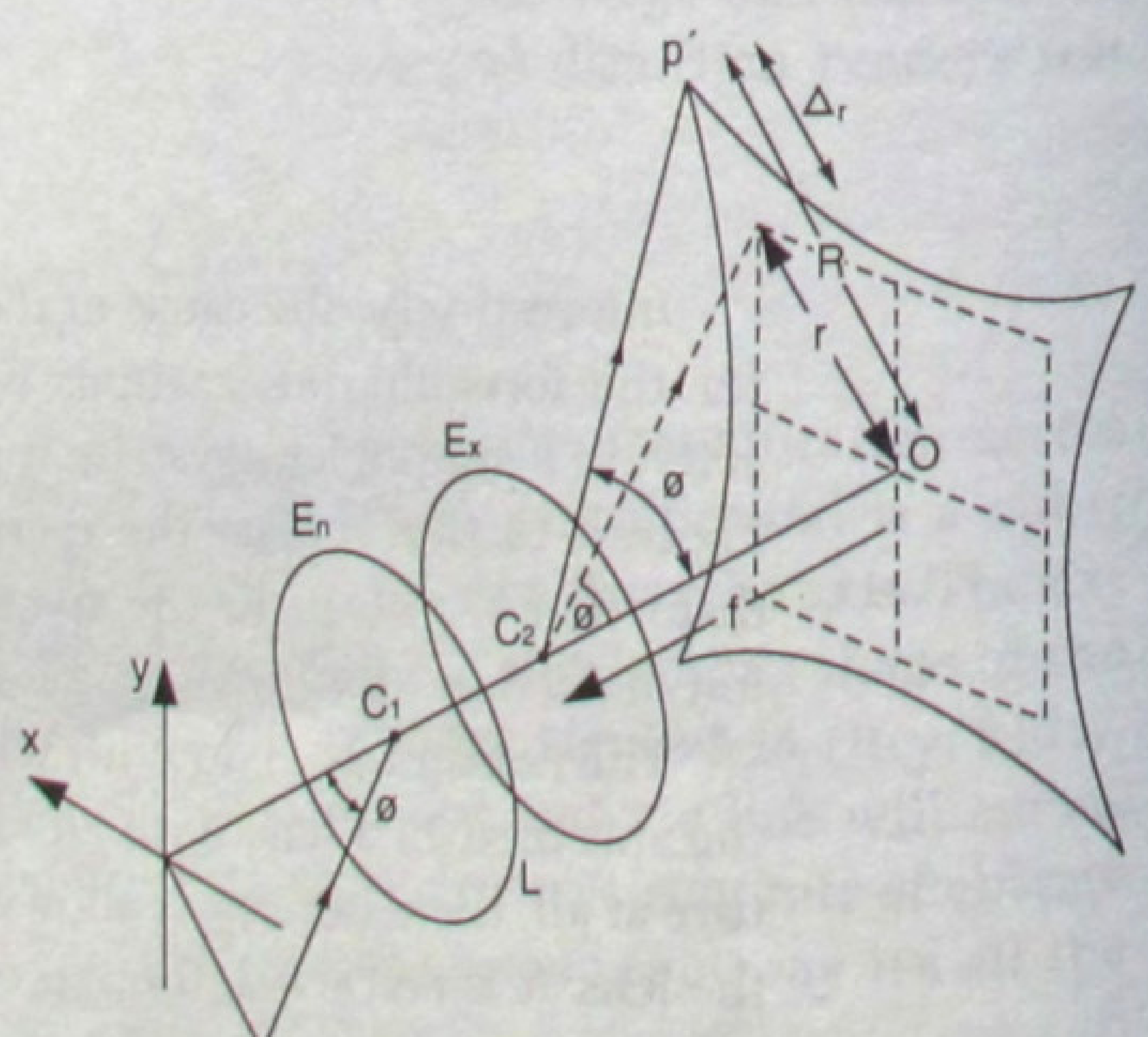


Figure 1-18b.
Optical Distortion: The lens L with pupils E_n and E_x forms an image P′ of off-axis object point P. The radial distance r is altered by distortion length Δr to give image height R. Principal ray angle θ is altered to θ by pincushion distortion. Reprinted from Sidney F. Ray, *Applied Photographic Optics: Imaging Systems for Photography, Film and Video.* London: Focal Press, 1988, p. 79.

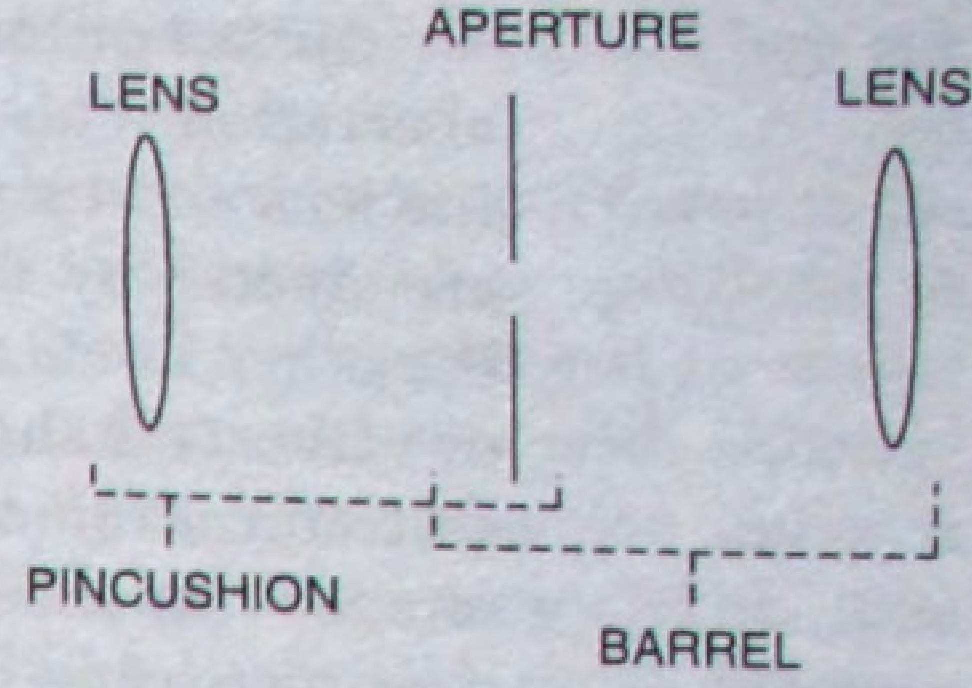


Figure 1-18c.
Symmetrical aperture position corrects distortion.

rays in the bundle emanating from a test grid. Remember, the chief ray is the central ray of a bundle. There is distortion-free, orthoscopic imagery. Now let's, just for giggles, move the aperture an appreciable distance away from the lens, either in front or behind it. The chief ray travels through the aperture and through the optical center of the lens as before. The remaining rays do not and are thus refracted differently and the image is magnified differently. Now these rays image in a different Gaussian image point than the chief ray, which is imaging in the same point as it was before. (See Figure 1-18.)

Simple, right? Not really, because photographic lenses are not a simple system of thin lenses. They are complex systems of many elements. Also, an aperture isn't necessarily the iris we control the T-stop with. And the center of a lens can exist outside the glass! This is one reason why the damn things cost so much! 'Cause they're like magic and hard to understand. I think wizards make them. And to add to the confusion, stopping down does not alleviate distortion at all. So what do we do to cure this problem?

Distortion is most commonly seen in telephoto lenses and retrofocus wide-angle lenses. Both types of lenses are compound lens systems. In a telephoto lens, the rear group acts as an aperture to the front group, giving pincushion distortion. In a retrofocus wide-angle lens, the front group acts as an aperture to the rear group. This aperture position gives barrel distortion. Look through a pair of binoculars backward sometime. A zoom lens can show both types of distortion as it is adjusted from its telephoto range to its wide-angle range, or vice versa.

Lenses are made of many lenses, and their relationship contributes to determining aperture position. Lenses and apertures can be arranged in a symmetrical way, such as an aperture between lenses. Here, one condition is counteracted by the other. See Figure 1-18. What about the iris? They try to place it where rays are crossing, and so it's out of the way of those pesky light rays. Designers often move it around for convenience.

Optical distortion is unlike other forms of distortion, and it is a true aberration. This form of distortion is caused by the optical physics of the lens and its relationship to the aperture. Other forms of distortion are created by factors that are more mechanical than optical. Some of the other kinds of distortion are geometric distortion, created by angle of view. This shows as convergence or divergence of parallel lines. Architectural cameras have orientable lenses and film planes to compensate for this effect. Perspective distortion is created by parallax of view over increasing distances (apparent distance compression). Subject distortion results from synchronization of shutter speeds with subject movement. Camera movement is also interactive here (strobing). Man, do you know distortion!

CHROMATIC ABERRATION

The order of presentation of the previous imaging defects is also the order in which they are corrected. But finally there can remain chromatic aberration. The foregoing Von Seidel aberrations may be corrected for, and chromatic aberration, though not corrected for, will not become apparent in monochromatic (single-color) light. But the real world is not in black and white, nor is it of a single color. It is really a combination of varying wavelengths and frequencies, with greater emphasis on certain bands than others in certain situations. The portion of the electromagnetic spectrum available to our senses is a small one. The visible part of the spectrum is even smaller. Imagine being able to dial down our perception to see infrared, or dial up to hear ultraviolet. This, by the way, would wreak all kinds of hell.

So let's take white light. Like white noise, it is made up of all frequencies/wavelengths of the visible spectrum. So in monochromatic light, our fully corrected lens is forming spatially correct images, in a focal plane, of point objects at any and all field angles. Let's switch to white light. Things don't seem quite sharp. We have failed to take in the dispersion properties of glass and especially those glasses that make up our lens. Glass has different refractive indices with respect to different wavelengths of light. And different glasses have different dispersion characteristics. The lens forms an image for each color of light present, and the total image becomes blurred. This is chromatic aberration: the differential refraction of different colors of incident light through different angles. Let's look at the last sentence and break it down: "differential refraction (a function of focal length) of different colors (wavelengths) of incident light through different angles." We

have three factors: refraction, focal length, and wavelength. They are related in the following way.

We already know that refractivity is inversely proportional to focal length. And in chromatic aberration, focal length is proportional to wavelength. So refractivity is (also) inversely proportional to wavelength. This means that the refractive index is higher with shorter-wavelength (blue-end/high-frequency) light. The refractive index is lower with longer-wavelength (red-end/low-frequency) light. Blue (short-wavelength/higher-frequency) light is focused closer (shorter focal length/higher refractive index) than is red (longer-wavelength/higher-frequency) light. Following this, we have, simply: refractive index/focal length of lenses is wavelength dependent in lenses not corrected for chromatic aberration. White light passed through a prism (remember, a lens is the shape of an infinite number of prisms) will form a primary spectrum, giving primary chromatic error. See Figure 1-19. Dispersion is the same through a prism or a lens, so we know that CA is independent of surface curvatures.

There are two types of CA: longitudinal chromatic aberration, which is sometimes called axial chromatic aberration, and transverse chromatic aberration, sometimes called lateral chromatic aberration. LCA is a lateral color shift.

In longitudinal chromatic aberration, blue light focuses closer than does red light. If a beam of light could be viewed from the side, a linear

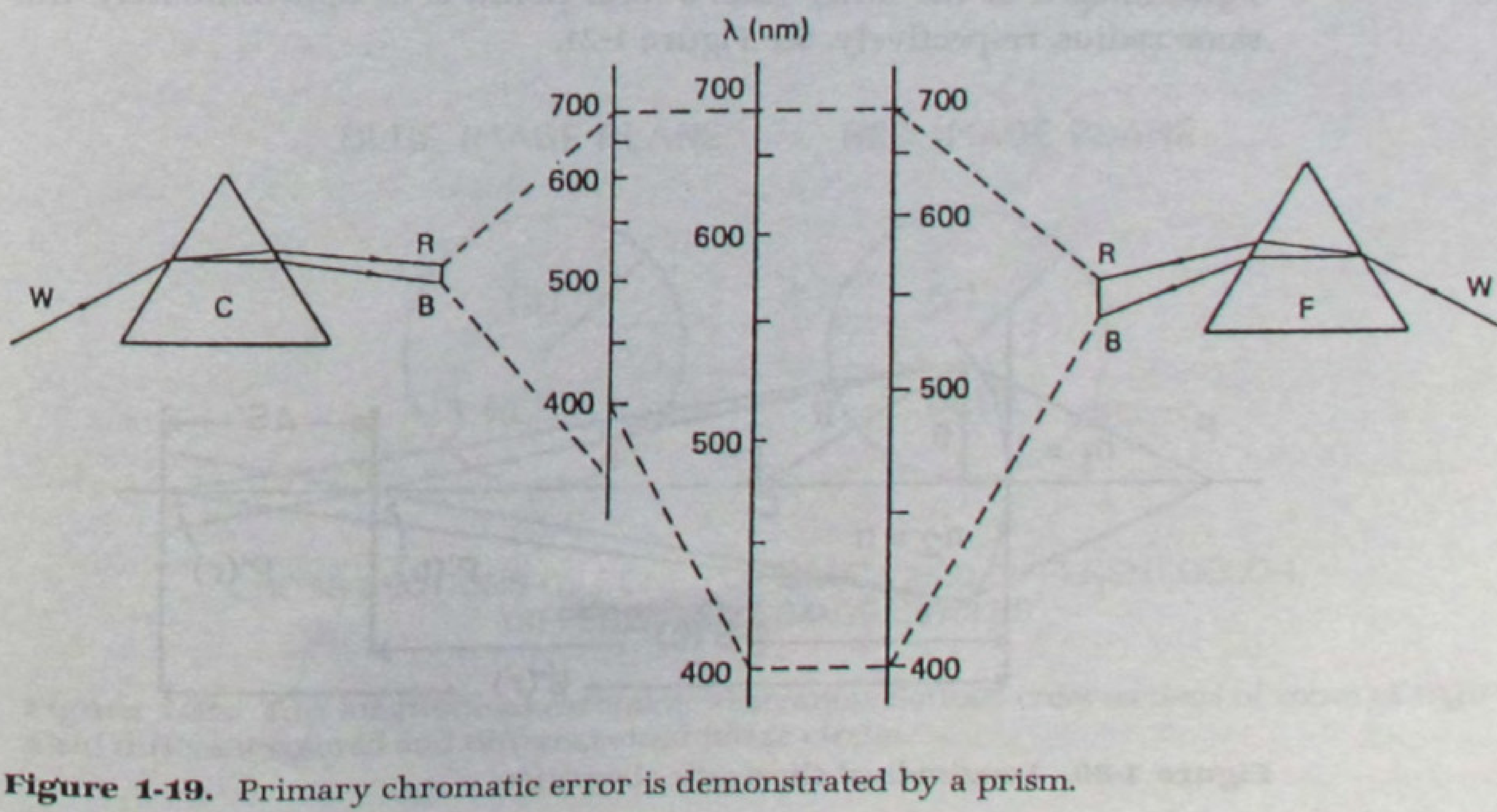


Figure 1-19. Primary chromatic error is demonstrated by a prism.

image along the optical axis will change from blue, through the color spectrum, to red as the beam moves farther away from the back of the lens.

From the front view of a focal plane, this longitudinal form of the aberration manifests itself laterally. Remember, focusing bundles of light rays can be thought of as cones of light. As the blue cone focuses closer, it fits inside the red cone. Viewed from the back, or base, of these cones, the focal plane renders a series of different-colored circles. The blue circle is the smallest in the center. The circles increase in size out to red, which is the largest on the outside. See Figure 1-20.

Let's take a closer look and step back inside our theoretical lens. Actually, let's exit the rear lens node and walk back toward the focal plane. We see, from the rear, the backs of cones of various-colored light. Imagine yourself walking down the axis line of Figure 1-20. We are really already inside the cones of light. The blue cone is narrowing sooner and faster than the red cone. Up in front of us, it is merely a point of pure blue light. Let's go there.

Here at the focal point of blue light, a red circle extends over our heads, around us, and below us. Up ahead we see where the red cone focuses to a point. Let's go there.

Here at the focal point for pure red light, we see a circle of pure blue light. It extends over our heads, all around us, and below us. The blue light rays in the cone-like bundle have crossed at their focal point, behind us and closer to the lens node. The rays of blue light and the blue they form are expanding again. See that each disk or circle of light, imaged at the other color's focal point, is of approximately the same radius, respectively. See Figure 1-21.

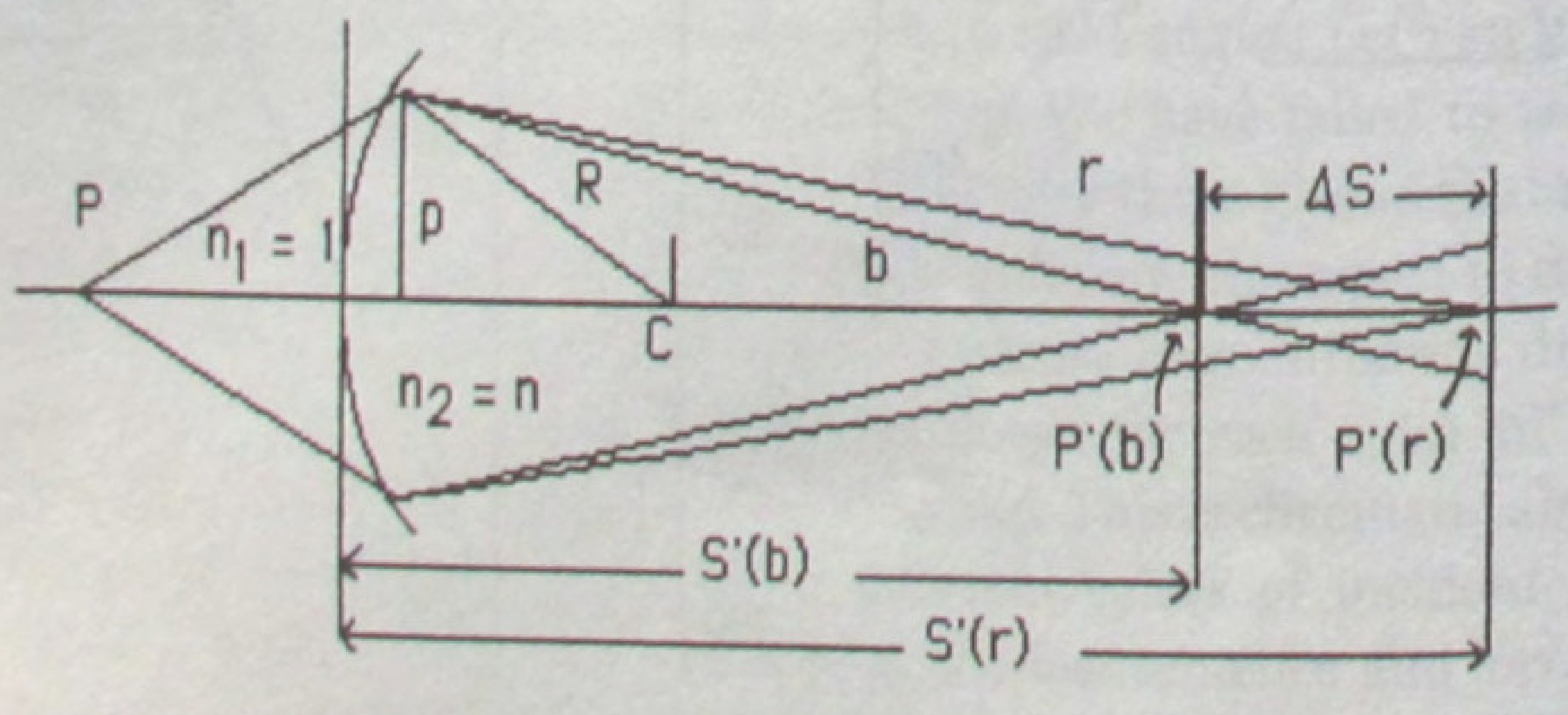


Figure 1-20. Longitudinal chromatic aberration.

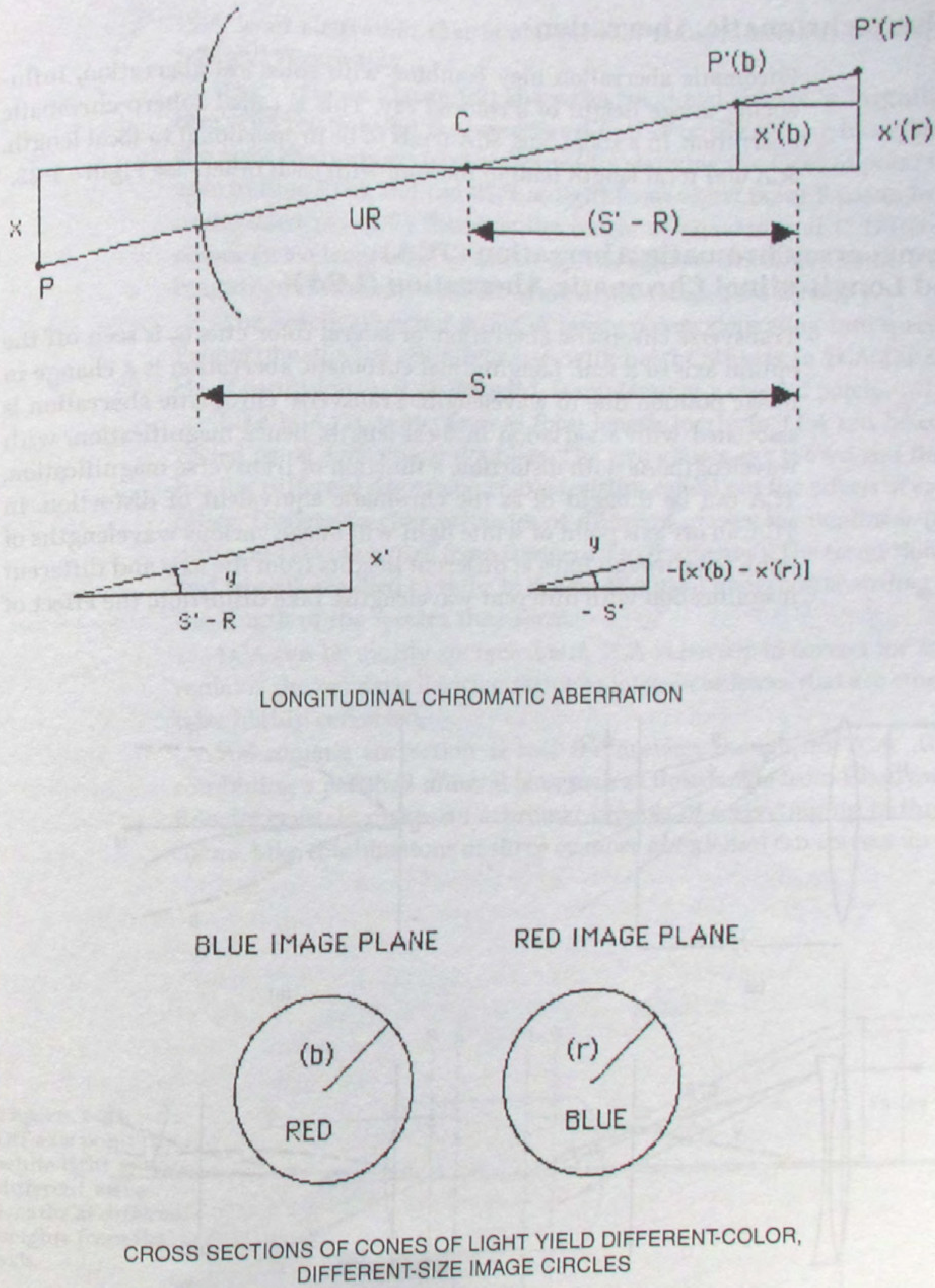


Figure 1-21. Top: longitudinal chromatic aberration. Bottom: cross sections of cones of light yield different-colored and different-sized image circles.

Sphero-chromatic Aberration

Chromatic aberration may combine with spherical aberration, influencing image height of a colored ray. This is called sphero-chromatic aberration. In a zoom lens, SCA tends to be proportional to focal length. SCA and focal length tend to increase with each other. See Figure 1-22.

Transverse Chromatic Aberration (TCA) and Longitudinal Chromatic Aberration (LCA)

Transverse chromatic aberration, or lateral color effects, is seen off the optical axis of a lens. Longitudinal chromatic aberration is a change in image position due to wavelength. Transverse chromatic aberration is associated with a variation in focal length, hence magnification, with wavelength. As with distortion, a function of transverse magnification, TCA can be thought of as the chromatic equivalent of distortion. In TCA, an off-axis point of white light will image various wavelengths of light, red through blue, at different heights from the axis and different magnification with different wavelengths. Like distortion, the effect of

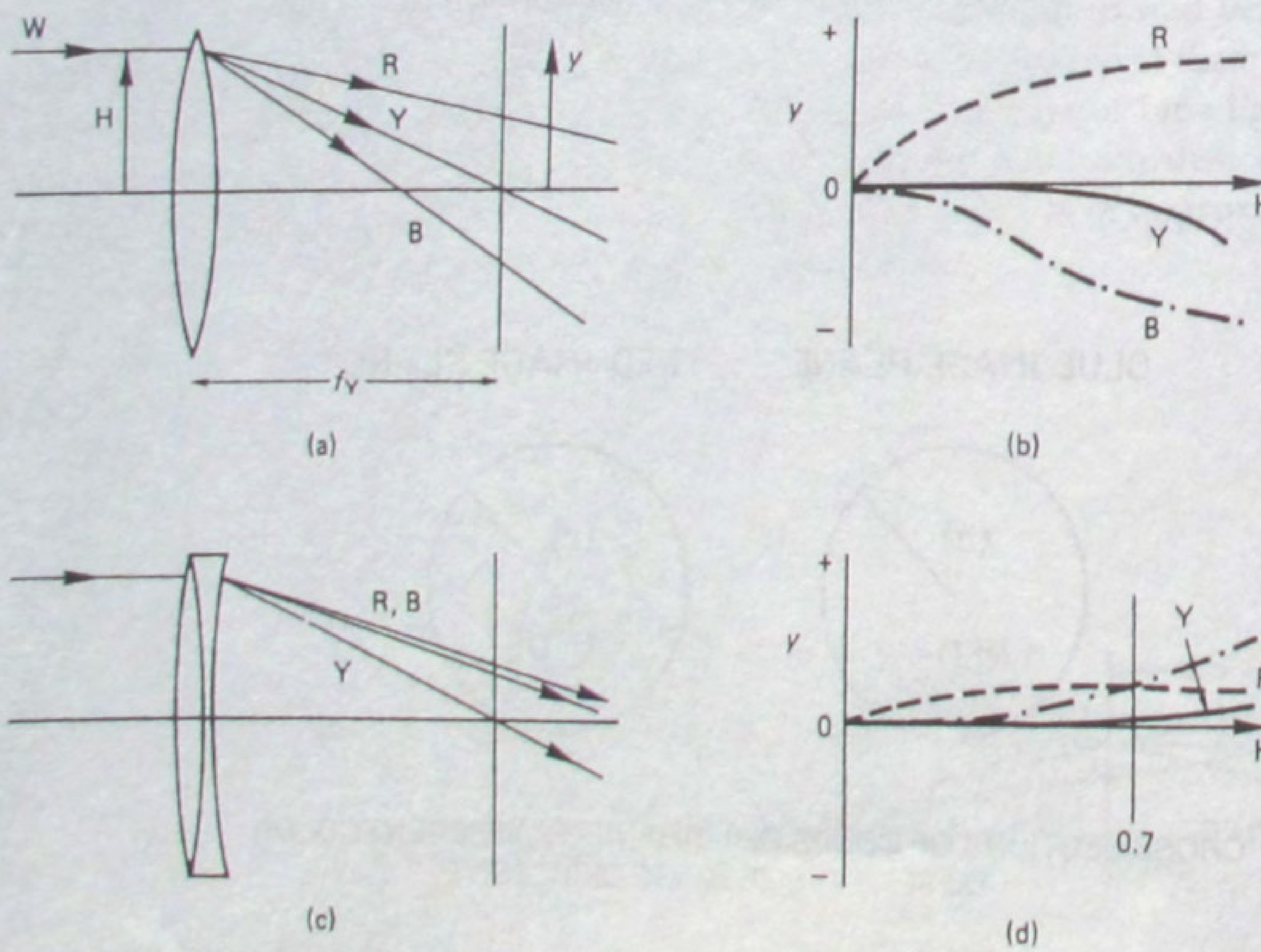


Figure 1-22. SCA combines variable refraction by zone (spherical aberration) with chromatic error.

TCA is an aberration that is oblique and nonsymmetrical. See Figure 1-21 and Figure 1-23.

The circles in Figure 1-21 show the fractional change in magnification. The relationship is proportional to that of the similar triangles in the same diagram, which are formed by showing the focus of point images in blue P′(b), and red P′(r), as light from object point P passes in an undeviated ray (UR) through the center of curvature at C. Different colors (wavelengths) that make up the light from object point P are magnified differently and are located and focused transversely.

The practical upshot is one of image points elongating into spectra. Proportionally, the effect increases with height off-axis. In TCA, the circle of confusion, as it is distorted, is rendered as a colored patch.

Like LCA, TCA increases as focal length increases. LCA can be corrected using achromatic doublets. The two glasses, say crown and flint, having different dispersion characteristics, cancel out the effects of each other. Dispersion characteristics of different glasses are nonlinear (no uniform rate of change from frequency to frequency). The terms "long" and "short" are used to refer to different optical materials, according to the length of the spectra they form.

LCA can be mostly corrected out. TCA is harder to correct for and remains the primary limiting factor to long-focus lenses that are otherwise highly corrected.

Achromatic correction is still the answer, though, to TCA. Also combining a polished mineral lens, such as those made from lab-grown fluorite crystals, makes an achromat capable of correcting up to three colors. Like combinations of three or more glass lenses can correct up to

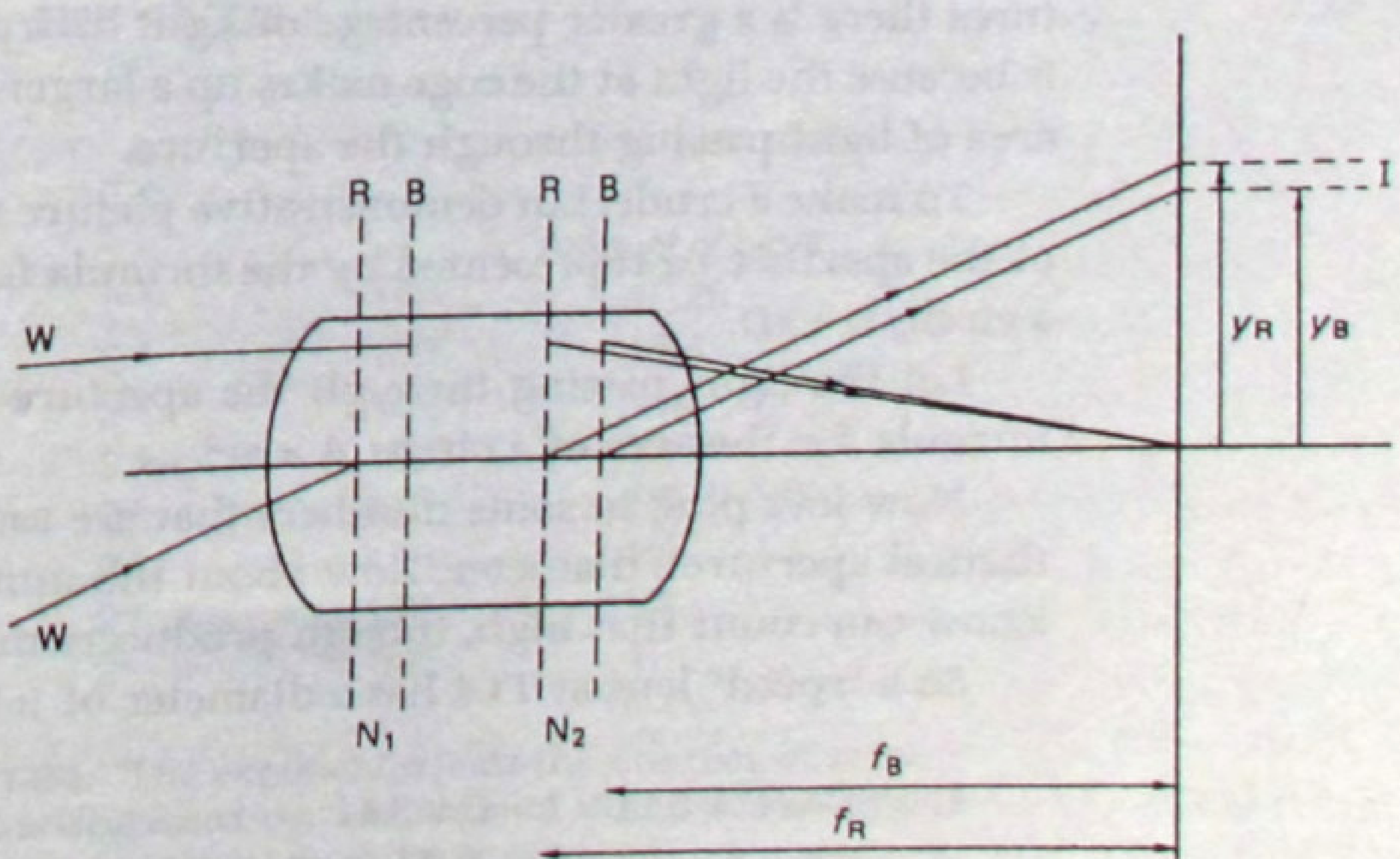


Figure 1-23. Off-axis point of white light images different wavelengths at different heights from the axis.

four colors. As correction goes up, the cost rises dramatically. This can be a limiting factor in and of itself.

The simplest, after-the-fact, in-the-field cure to all aberrations except distortion is stopping down. At smaller apertures, a greater portion of light used passes through the center of the lens. This is the best part of the glass in a lens. Stopping down increases depth of field. This increases focus, not sharpness, but image degradation due to aberration is minimized. However, as stopping down is continued, past a point, to smaller apertures, contrast and sharpness begin to suffer as the effects of diffraction arise. (To better understand aberrations, consult *Applied Photographic Optics* by Sidney F. Ray.)

DIFFRACTION

Diffraction simply is a blurring of an image due to light spread as it passes next to and interacts with the physical edges of the aperture in the lens.

This may occur in long lenses outside, where small apertures are used to increase the depth of field and to expose properly in excessive outdoor light.

Light travels in a wave motion rather than a straight line. When it passes through a tiny aperture, it spreads out into the geometric shadow region. The actual edge of the aperture produces secondary wavelets. In a circular aperture, like that in a lens, we get concentric light and dark rings around a central bright spot. The light rings diminish in intensity with distance from the center.

Diffraction increases as apertures decrease, because at smaller apertures there is a greater percentage of light diffracting at the edge. This is because the light at the edge makes up a larger percentage of the total area of light passing through the aperture.

To make a crude, but demonstrative picture of this, let's let the edge of the aperture be represented by the formula for the circumference of a circle: $C = \pi D$.

Let the light passing through the aperture be represented by the formula for the area of a circle: $A = \pi r^2$.

Now let's plug in some numbers that are easy to use for our hypothetical aperture's diameter. How about the number 1. Most assistants I know can count that high, though producers might argue this.

So a "speed" lens at T1.4 has a diameter of 1: $D = 1$.

$$C = \pi D = C = 3.14 \times 1 = C = 3.14$$
$$A = \pi r^2 = A = 3.14 \times (1/2)^2 = .785$$

The ratio of the circumference to the area is

$C/A = 3.14/.785 = 4$

Now let's stop down to T16. This is seven stops down from T1.4. Let's assign the number 1 to represent the amount of light at T1.4. Now as we stop down we halve the light intensity at each decrement. See Figure 1-24.

$C = \pi D = 3.14$
$A = \pi r^2 = .785$
$AE = 3.14/.785 = 4$
E = aperture (entrance pupil)

Ratio of C/A at T1.4 = 4

$C = \pi D = 3.14 \times 1/128 = .0245$
$A = \pi r^2 = 3.14 \times (1/256)^2 = .0000477 = C/A = .0245/.0000477 = 513.62$

Increase in Amount of Diffracted Light

128 TIMES = 513.62/4 = 128.4067

If we represent the number of stops we have decreased the aperture by with an exponent, we can write $2^0 = 1$, in the interest of simplicity.

If $2^0 = 1$ at T1.4 and we close the aperture seven stops, we get

$2^7 = 1/27 = 1/128$

T-stop			*Amount of Light*
16	2^{-7}	$1/2^7$	1/128
11	2^{-6}	$1/2^6$	1/64
8	2^{-5}	$1/2^5$	1/32
5.6	2^{-4}	$1/2^4$	1/16
4	2^{-3}	$1/2^3$	1/8
2.8	2^{-2}	$1/2^2$	1/4
2	2^{-1}	$1/2^1$	1/2
1.4	2^0	$1/2^0$	1

Figure 1-24. The exponent equals the number of stops aperture is decreased by. The amount of light is halved with each incremental decrease in stop.

So there is 1/128th the amount of light passing through our aperture at T16.

And to get this, we have diminished our formula to 1/128th of its original value. So we have diminished our diameter by 1/128.

$$D \times 1/128 = D/128$$

So if previously D = 1, now D = 1/128.
So in $C = \pi D$, we have:

$$C = \pi \times 1/128 = 3.14 \times 1/128\ C = 3.14/128 = C = .0245$$

And in $A = \pi r^2$, we have:

$$A = \pi(1/256)^2 = 3.14 \times (1/256)^2 = .0000477$$

The ratio of circumference to area at T16:

$$C/A = .0245/.0000477 = 513.62$$

So at T1.4, the amount of light available for diffraction at the edges can be represented by 4. At T16, the amount of light available for diffraction at the edges can be represented by 513.62.

So now comparing diffraction numbers at T16 with diffraction numbers at T1.4, we have:

Diffraction # at T16/diffraction # at T1.4 = 513.62/4 and
513.62/4 = 128.4067.

So at T16 from T1.4, the amount of light available for diffraction at the edges of the aperture is increased approximately 128 times! See Figure 1-23.

Diffraction is the effect of light traveling through small apertures, but also it is the effect seen when light travels around small barriers.

Sometimes this degradation is used to advantage or disadvantage by DPs, who wisely or foolishly place "nets" near the back of lenses for purposes of diffusion. As the light travels around the tiny barriers, secondary wavelets are formed. These tend to diffuse our image, pointwise. But the light is also diffused slightly by its component colors. It is refracting.

A physicist's zone plate made up of tiny slits can be assigned a focal length. Imagine a lens without glass. But more interesting, or at least of more use to you, is that the guy who likes to monkey with nets is often

the same guy who likes to use lots of filters. Including colored ones like blue through red... So?

Different wavelengths of light interact differently with barriers and edges. Longer-wavelength light (red) travels around obstacles with less disruption than does shorter-wavelength light. This is why ultraviolet tends to scatter into shadows, giving them a bluish cast. This is consistent with Huygens's treatment of diffraction, but save that for cocktail parties. No one will believe you, anyway. Now back to more useful stuff. The interaction effect of small apertures, nets, and colored filters may come to some consequence if all variables are combined at extreme values. Due to wavelength interaction, you may want to suggest the most optically desirable position for the use of colored gels in front of or behind a net that is used. This allows you to increase or diminish a desired effect or an undesired artifact. If only certain options for position are available, you can at least know the potential effects.

The perfect lens is diffraction limited. The perfect lens does not exist, at least not in cinematography. There are lenses closer to this theoretical limit in some kinds of reproduction. A diffraction-limited lens would be corrected to the point where its minimum blur circle is equal to the theoretical minimum blur circle (of confusion). Residual aberration in the lens will make the circle larger, but no degree of correction can make the circle smaller than that dictated by its aperture. This is a diffraction-limited lens. There is, however, a zone/range of optimal performance of a lens that exists between its aberrational limits and its diffractional limits.

This discussion also implies an optimal T-stop range on a lens, between aberrational large apertures and diffractional small apertures. Look for it at prep. Be able to suggest it.

LENS TESTS/LIMITATIONS

So that's the story of lens performance in sharpness and resolution, technically. But the perception of these factors is human and therefore subjective. People go to see movies, not images on test charts. Resolution is also a function of contrast. A lens of high resolution, as measured on a test chart, can give a seemingly very-low-resolution performance when viewing distant objects with low-contrast detail.

A lens, though a scientific instrument, is often used creatively to tell a story, set a mood, even explore a feeling. So using more organic terms, let's talk about impression by experience.

A photographer develops a feel for a lens. A good director does this too. Almost on a subconscious level, he assesses a lens empirically,

through using it many times—looking through it and photographing with it.

But as a rule in filmmaking, where camera systems are rented and not owned, the same lens is not used by the same cinematographer repeatedly. Here a DP uses a type of lens repeatedly, not a particular lens. He becomes aware of desired and/or undesired characteristics of a type of lens.

Lens tests like photographing lens charts and newsprint are of limited value. But watch this.

Let the hypothetical resolution of a lens be 50 lines per millimeter:

$$R = 1/50$$

Let the hypothetical resolution of a photographic emulsion be the same:

$$R = 1/50$$

The value for film emulsions is found through an edge test. An object's image is not rendered onto the film by a lens, but by an edge physically placed against the film. Light is then projected onto the film and the resolution of this "exposed" edge is measured. Photographing light through a lens and onto a photographic emulsion causes the combination of the resolution values for the lens and the emulsion, giving us:

$$1/50 + 1/50 = 1/25$$

We're down to 25 lines per millimeter. The lens test itself proves a limiting and diminishing factor in determining resolution. Still, it might give an approximation of lens performance with a particular film stock, at a desired T-stop, that a DP is interested in using on a particular shoot.

But to exactly quantify a lens? One formula proposes that the resolution of a lens is a function of the relationship of an f-stop number to the wavelength of light.

$$R = (\text{f-stop\#}/\text{wavelength})\ \text{mm}$$

Only an approximation is possible due to the large variation between red light at 700nm (nanometers) and blue light at 400nm.

$$R = (\text{f-stop\#}/2000)\ \text{mm}$$

If you plug in the numbers, with a lens set to f4:

$$R = 4/2000 = 1/500\text{mm}$$

I wish.

At f8 we have:

$$R = 8/2000 = 1/250\text{mm}$$

Now let's look at large apertures. Everybody likes fast lenses. Things really fall apart at f2:

$$R = 2/2000 = 1/1000\text{mm}$$

Lenses can't even approach this kind of performance because of aberrational effects at large apertures.

At smaller apertures, f16 yields:

$$R = 16/2000 = 1/125\text{mm}$$

At f32,

$$R = 1/62.5$$

Resolution is limited by diffraction, but lenses do much better than this. We know good lenses perform best in the middle of their aperture range. Still, *R* will be only a bit better than 1/200, or R = 1/200, at the time of this writing. These are the tiniest grids on projected charts in lens lab tech rooms at rental houses. The tiniest grid on a prep chart used on the rental house floor is 100 lines per millimeter.

So in photographing lens tests, we go beyond measuring a lens's resolution. Tests aimed at quantifying a lens prove often only to be cute, at best. Remember, photographing these charts in tests includes the artifact of the resolution limitation of the film's emulsion as well. Other contaminants to the data include camera vibration, ambient vibration, and the tester's ability to focus. (There's that word again.)

Lenses can be, should be, and are tested on an optical bench, with artificial stars. But DPs shoot movie stars, not calibrated object points of reference. Artificial stars don't make people swoon or kids scream. There is no practical way for someone other than an optical technician to quantify the performance of a lens, but these numbers serve only as a jumping-off point.

Using a lens in the conditions under which it will be used is the

best test. At prep, look at detail in distant views. Do you like what you see?

GENERAL LENS SURVEY AND RELATED CHARACTERISTICS

Why lens choice? Somewhere there is a mathematical proof that shows that no lens can produce an equally good image at all distances or even at two different distances. A lens makes the best image of an object at a distance for which that lens was designed originally.[20]

I don't think the need for lens choice (by directors, DPs, and operators) is so much based on an obscure and dust-covered math model. The need for lens choice is based on two things: utility and art, or speed and coverage. Utility is sometimes accommodated by speed, sometimes by coverage. Artistic expression can be achieved sometimes by the physical/optical limitations of apertures, sometimes by the dictates of field angle.

So given relatively comparable high performance, across the board, one lens is distinguished from another primarily by its speed and its coverage.

A lens is chosen for the same two reasons. Minimum focus distance can be a determining factor. This is, to a degree, tied in with coverage.

Speed and coverage? Speed or coverage? Primes or zooms? What are a DP's priorities for the task at hand? For low-light situations where we want to take advantage of high-speed film stocks, high-speed primes are the most likely candidates. For a practically infinite selection of focal lengths, some fifteen zoom lenses are offered in 35mm at the time of this writing. Some emphasize wider angles with smaller zoom ratios. Some zooms cover a fairly normal range, comparable to focal lengths available in a standard set of primes. Some zooms emphasize standard to long focal lengths with large zoom ratios. There are vari-focal lenses that have been converted to focus "tracking" zoom lenses. This means the lenses hold the same focus reference on the lens collar as the focal length is changed. Their range usually starts from long and goes to very long focal lengths. An example would be the Cannon 150mm–600mm lens, with a four to one zoom ratio.

Ways to achieve varying coverage at both ends, wide and long, are through special application lenses such as macros and telephotos. And to enhance "reach" capability at both ends, diopters and telextenders are available. These may be used on zooms as well as primes. Obviously, a way to achieve varying coverage, if consolidation of gear is not important and image quality must be of the very highest degree, is to

change primes a lot. The difference in image quality between zooms and primes is growing more negligible all the time.

Primes can be changed from 9.8mm up to 20mm, every other millimeter. Just skip the odd numbers. They can be very fast: T1.4. The wide-angle lenses are well corrected for barrel distortion, which is hardly noticeable, starting at 12mm, though it sees everything except a specially designed shadeless filter holder. The 9.8mm lenses and wider, including aspheron converters, are really only effects lenses. From 20mm to 100mm, a change in focal length is available every 5 to 10 millimeters. The 16mm through 32mm close-focusing primes allow the helical thread an additional two turns, decreasing minimum focus distance dramatically.

The lenses ranging in focal length from 32mm to 100mm photograph with realistic, nonobtrusive perspectives. This range contains the focal length of the "normal" lens. The 50mm lens's viewpoint and coverage are considered most like the human eye's perspective in 35mm. I can hear some DPs scoffing at this. Well guys, it's your call. For the other formats: divide the focal length by the number of times the desired format goes into 35mm. For 16mm, the factor is two; for 8mm, the factor is four. This rule applies to focal length conversion equivalents between formats of 35mm and 8mm. Video approximates 16mm.

From approximately 100mm through 200mm are lenses that are often desired as portrait lenses. Their speed and long focal length, combined with their coverage, lend pleasing effects to this style of rendering.

Zoom lenses cut right across this range. A 14mm to 70mm zoom is fast, heavy, and expensive. The three reasons are engineering, glass size (large apertures/wide field angle), and correction. The 20mm to 100mm or 18mm to 100mm are workhorses. They are the most commonly chosen, due to the high applicability of their focal length range. The 25mm to 250mm is a preferred sports and action lens, often used in exterior settings for nature documentary material as well. It has practical focal range and extends its reach to the lower limits of long-lens capability. Competing with telephotos as a zoom lens is the converted 150mm to 600mm vari-focal lens. Converted to a zoom lens, it holds focus as its focal length is changed. Flare and fog in extreme backlit conditions have been associated with this lens.

Telephotos and long lenses range from 200mm to 1000mm. Trading speed for focal length, maximum aperture can be T5.6 or even T8. Part of the drama created by extreme telephoto lenses is due to perspective compression, which is a natural phenomenon of distance parallax. Distances vanish to a point. Your eye can distinguish between close distances. This ability degrades with increasing distances, due to the paral-

lax effect inherent in viewing them. Apparent distances vanish or compress. The difference in apparent differences diminishes on a curve exponentially as distance observed increases. This is partially why very large objects that are very distant seem much closer than they are. Their great size makes them appear large, even when viewed at large distances. The magnitude of these large distances cannot be judged accurately due to parallax compression.

A telephoto lens also can single out and create great emphasis on an object. This is indirectly due to where the infinity scribe is etched on a lens. Lens focus of infinity on a lens doesn't mean the lens is focused on what is classically defined as infinity, or forever. The infinity mark is the focus of a finite distance from the focal plane. For a particular lens focused at that distance, an object receding from or approaching the lens will not appear to change focus significantly. This is why if you're pulling focus on an object that is approaching you from infinity, you must not overanticipate the focus pull. Let the lens rest on infinity for a while. It works. Many assistants talk about letting an approaching object "push" your focus. This is Zen. The infinity setting is like a hyperfocal distance setting for all stops on a long telephoto, with its accompanying short depth of field. You must focus on an object distance that is very great to achieve depth of field great enough so that the far limit extends to infinity. On wide-angle lenses the infinity scribe is etched anytime after 12 feet. It is etched after 100 feet on a 100mm lens. On a 1000mm lens the infinity scribe is etched on the lens after the scribe for 1000 feet. Thus at any of these lesser distances, a long lens can pick out one object and throw everything else out of focus. I think the factory should note a footage etching next to the infinity etching. If possible, one should figure out what distance the infinity scribe refers to. This becomes important with approaching objects. Receding object points become so small that they begin to interact with the resolution limits of the lens. Thus, it serves no purpose to continue to adjust focus for objects receding to a distance past the infinity setting.

Telephoto and wide-angle lenses achieve their powerful effects at their respective ends of the focal range, while still allowing for the practical limitations of the rest of the photographic system, by specialized design. Though a telephoto is thought of in a "long lens" category, it is physically shorter than a long lens of comparable focal length. For a wide-angle lens to accomplish its task, its back-focus distance would be so short that the rear element would shatter a spinning mirror if it were not for the retrofocus design. Here are the crude basics of these designs.

How is a telephoto lens physically shorter than a long lens? Its node

of emission has been optically moved forward. This is done by placing a negative lens behind the front positive lens. This allows for the effectively long back-focus distance that is required of long-focal-length lenses. This allows the actual distance between the back of the lens and the focal plane to be greatly reduced. See Figure 1-25.

A wide-angle retrofocus lens accomplishes the reverse. As focal length decreases, so does back-focus distance. This can be a problem in cameras with spinning mirror shutters, or other optical mechanical space considerations, in front of the film plane. Placing a negative lens in front of the positive lens allows effective back-focus distance to be decreased optically, leaving room for the rear element to clear the shutter or room for other considerations in the system. See Figure 1-26.

The retrofocus design was used to allow room for the beam-splitting prism in the Technicolor camera of the 1930s. Being a three-strip camera, it had multiple film gates, requiring the prism to divide the light among them.

A special-purpose lens at the short end of the focal-length spectrum is the macro lens. It allows filming at very short object-film distances, giving great small-image magnification. The lens is allowed to bellow

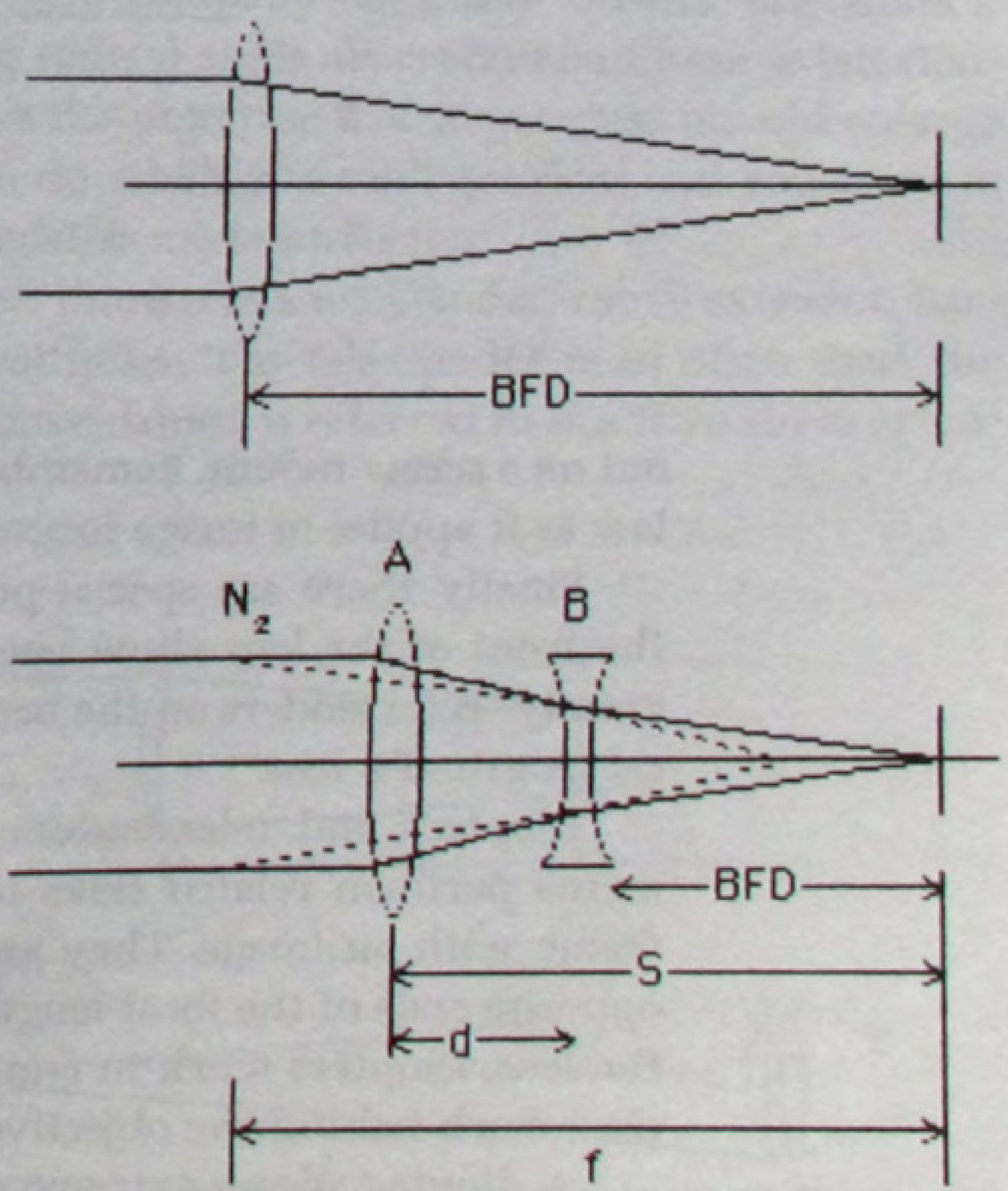


Figure 1-25.
In a telephoto lens, back focus is optically increased in a physically shorter lens as the node of emission is moved forward by a negative diverging lens.

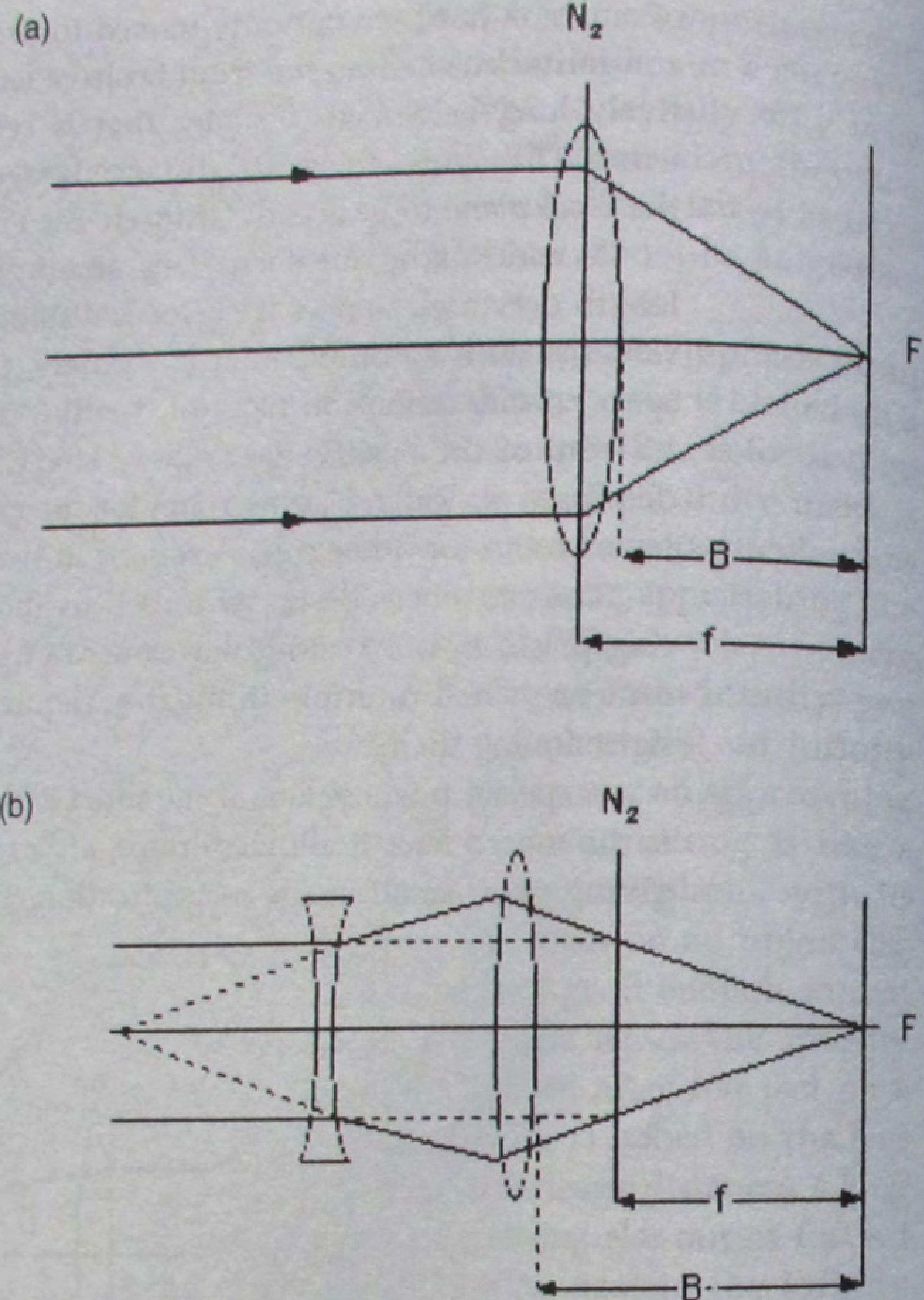


Figure 1-26.
In a wide-angle retrofocus design, back focus is optically decreased as the node of emission is optically moved backward by a negative diverging lens placed in front of the positive lens (group).

out on a screw mount. Remember, at prep and shoot, the inverse square law as it applies to image magnification and light-intensity loss.

Finally there are special-purpose attachments. Diopters placed on the front of the lens allow one to minimize minimum focus distances greatly. Telextenders on the back of a lens can effectively double the focal length of a lens.

Diopters and telextenders both enhance coverage. These attachments perform related tasks in that they are usually used to fill the frame with an image. They are opposites in their mechanics, work at opposite ends of the focal-length range, and are used at opposite ends of the lens. Diopters work in front of the lens and the aperture. Telextenders work behind the objective lens and the aperture.

A diopter allows extreme close-up photography. Because the back-

focus distance remains unchanged, zooming is possible with no loss of focus. Minimum focus distances of 5 feet can be reduced to 4 inches. This is an absolute extreme, achieved with a diopter of power +10, and is not commonly used. Negative diopters are available. They are negative diverging lenses that push focus away.

An object placed at the far focus of the diopter sends effectively parallel light to the camera. Its image is rendered sharp when the primary lens is focused at infinity. Varying focus on the primary lens gives the limited close-up range.

The common range of powers of diopters used is +½ to +3. Their focus ranges are 39 to 79 inches and 10 to 13 inches, respectively. A diopter is a positive, converging meniscus lens. A diopter decreases minimum focus distance (MFD) because incident angles of rays diverging from an object are effectively increased to a greater angle. They effectively shorten the focal length of the system. Similar (triangular) convergence angles are increased, decreasing the height of the similar triangles on the transmitted side. The height of the similar triangle on the transmitted side of the lens is the dimension of the focal length. In essence, the focal point is pulled forward to the image plane. See Figure 1-27.

The diopter is used in front of the objective lens and the aperture. There is no light loss. It allows image enlargement without magnification increase. It magnifies the object in object space, not the image in image space. There is no accompanying image quality degradation found when magnifying central angle aberration and haze as telextenders do. A diopter allows the objective lens to get close up and enlarge objects. But what do you do when you can't get close and you want to make an image really big? Use a teleconverter.

A teleconverter is also known as a telextender, range extender, Barlow lens, or matched multiplier. The telextender most often used, the 2×, while called all the above names, is referred to as a "two times exten-

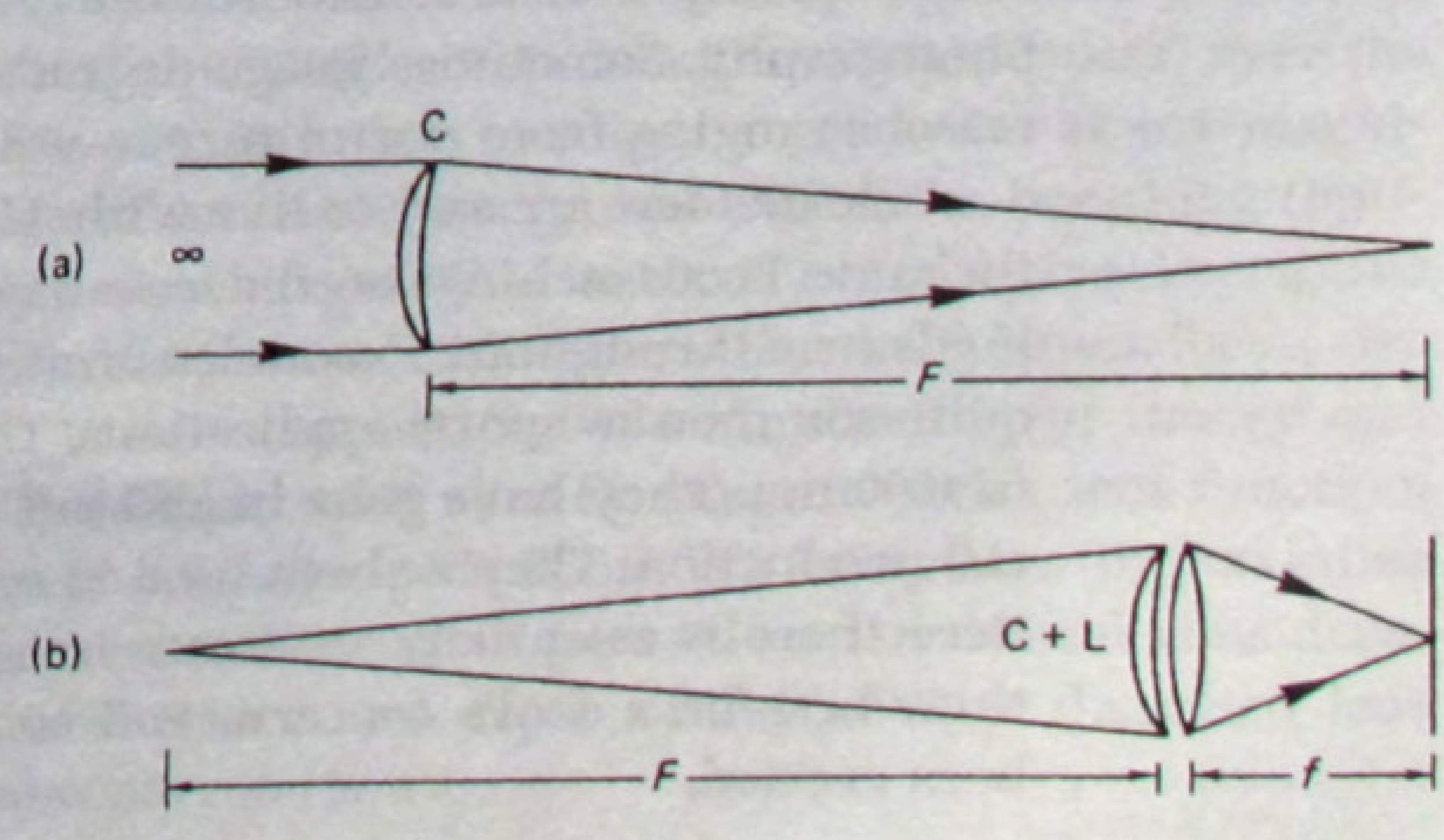


Figure 1-27.
A positive diopter increases the angle of incidence of rays diverging from an object point.

der, two ×, or doubler." In video it is sometimes called a two-× tele (telly). Like the diopter, it is a supplementary lens attached to the primary lens system. It works at the long end of the focal-length range and at the back end of the lens. The diopter is a positive lens. The telextender is a negative or diverging lens system. It is placed between the lens and the camera body. The combination of primary lens and supplementary lens works on the telephoto principle. The primary lens can now be thought of as the primary front group. Light rays are then diverged by the negative rear group (telex system). This increases effective focal length. The telextenders used in motion-picture photography range from 1.4× to 2×, most commonly. There is a 3×, but its use is rare. Telextenders magnify the height and width dimensions of an image. Because this magnification takes place after/behind the aperture, there is light loss, according to image area magnification. Again, it is calculated by the inverse square law, the mathematics of which are discussed earlier. For simplicity, open up a stop for each time the × is multiplied by the number preceding it.

A teleconverter's power is a function of separation distance between positive and negative groups. See Figure 1-28.

In the figure, as d decreases, its power increases. But there is also an increase in back-focus distance. So the tube of a more powerful teleconverter, with a smaller d, will still be longer than a less powerful extender with longer separation d. I think opposites like this are very Zen.

People still scoff at telextenders, complaining of poor image quality. Early designs used fewer elements and produced overcorrection in the sagittal plane. Remember, this causes astigmatism and Petzval curvature. Current designs use more elements of better refractivity. Petzval curvature is reduced many times to acceptable limits. It's true that telextenders do magnify central-angle aberrations of the primary lens. Aberration haze is increased, and this makes for less contrast. Performance is diminished, but only slightly. Telextenders give very good image quality and are used routinely in big-budget motion-picture photography. Sometimes image degradation is sought on purpose, for reasons ranging from portraiture to wild expressionism.

Telextenders are easy to live with. Minimum focus distances remain the same. Focus etchings on the lens may experience a slight shift. Focus holds true throughout a zoom lens's entire range. Their use on zooms is quite common in sports applications. They're used on telephotos of up to 1000mm. They have gone in and out of style in big-budget commercial production. They've been used in series: a 1.4× + a 2× + 1000mm lens. Here there is essentially no focus. Images are color swatches. Aberrations become a fool's concern, and some very dramatic images have been created.

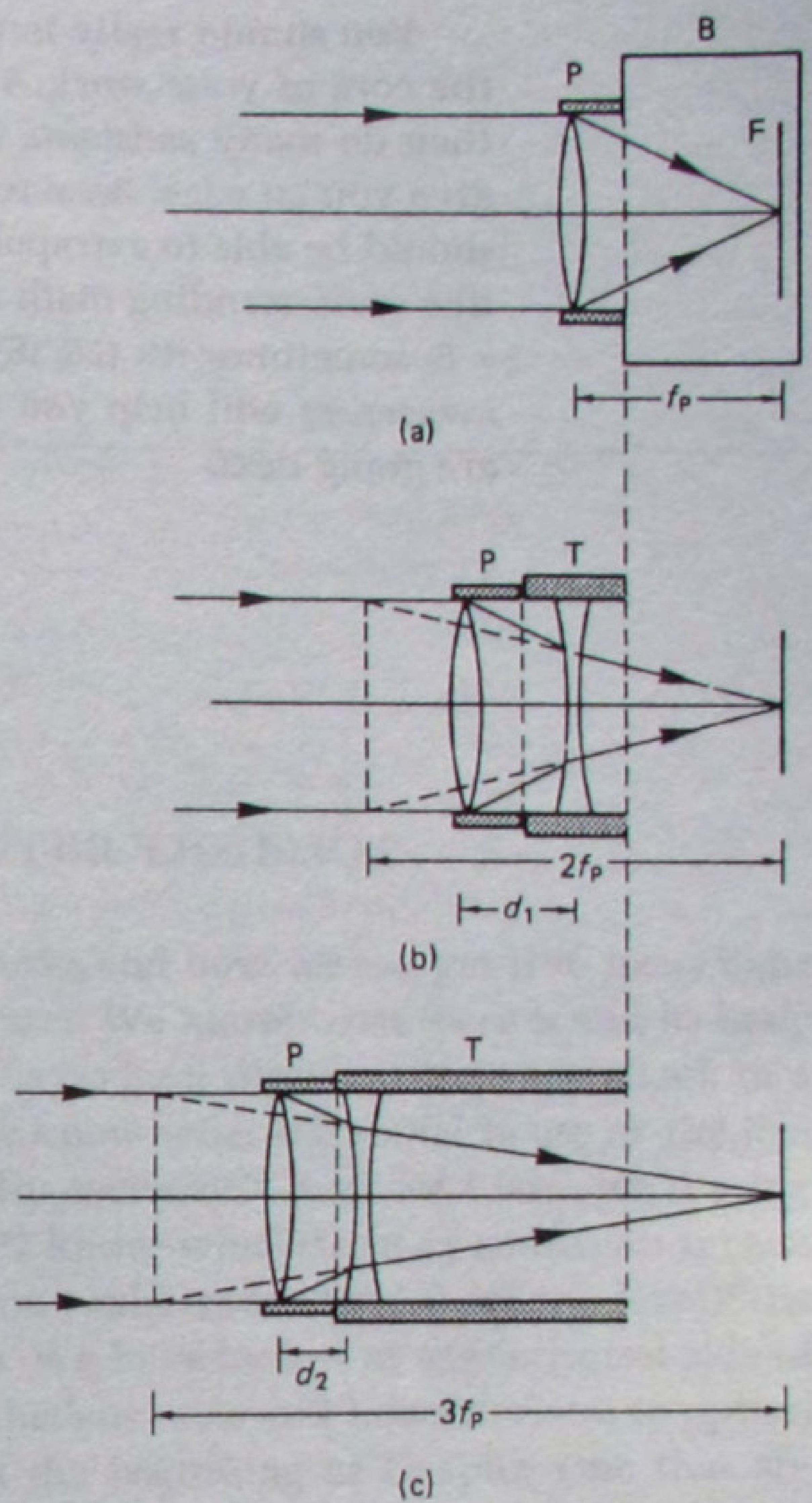


Figure 1-28.
Principle of the Teleconverter: (a) Prime lens P is in camera body B with focal plane F. (b) ×2 teleconverter T in tube of length $f_T/2$, separation d_1. (c) ×3 teleconverter in tube of length $4f_T/3$, separation d_2. Reprinted from Sidney F. Ray, *Applied Photographic Optics*, 2d ed. (Oxford: Focal Press, 1994).

This treatment of lenses is the most basic of design theory. Modern engineering is going out of sight. Zooms will maintain "specs" over the focal range and have no light loss or image degradation at any magnification. Movement of multiple lens groups eliminates breathing (optical zooming with focus change). This has been a qualitative descriptive treatment of the basic science of light interaction with lenses, focus, and basic lens design. We've discussed a little bit about light theory and wave motion. We've talked a bit about geometric optics, lens function, and our core concern of that aspect: focus. We know how to maximize focus through an understanding of general and technical considerations of hyperfocal distance and depth of field. We've discussed lens mechanics and lens characteristics.

You should really have a good understanding of the system that is the core of your work. You now have a stronger grasp of the subject than do many assistants who do their job by rote. This is intended to give you an edge. Because you understand the underlying theory, you should be able to extrapolate to situations that aren't cut and dried. It's like understanding math instead of just tables. The world isn't always 7 × 8, sometimes it's (56/16) × (128/8) or (49/7) × (64/8). Your increased awareness will help you in prep and in the field, which is where we are going next.

2

Focus

FOCUS BEFORE, DURING, AND AFTER THE SHOT

Now we know how a lens works and how we can get it to focus light emanating from certain distances. We know what focus is and its basic elements: depth of field and hyperfocal distance. We understand, in a basic way, aberration, and we know what the rental house or the factory means when it says "fully corrected." And we know what a big talker means when he says, "I know what circle of confusion means, but I couldn't explain it so you could understand it (at my level)." He doesn't know what he means. We have looked at the technical side of the positional adjustment of the lens node and how it relates to optical focus. You'll remember from the beginning of Chapter One that another thing focus is dependent on is the humans who twist the helical mount on the lens. Some above-the-line production execs don't view crew people as human, however. So after having looked at all the technical contingencies of lenses and related hardware, let's look at some of the software.

Focus is like love. You must get it before you can give it (developmentally speaking). There are a number of ways to do this. Focus can be estimated. This may seem obvious, but there are more ways than you might think to do this, and they are more rigorous and scientific than you might think. There are certain dimensional relationships in nature and in the world. With a little math, ingenuity, study, and practice you can take advantage of the methods and ideas offered here. Possibly you may develop some of your own.

There are ways to judge short distances by visual memory. These same distances and longer distances can be judged using certain simple relationships found in the trigonometry of three very standard right

triangle functions. The technique also borrows from cybernetics. We'll use cybernetics again later, when we discuss a few focus-pulling methods. But back to getting focus.

Do you know that humans tend to do the same thing every time? You can take advantage of this knowledge to judge and hold focus even in tight ECUs (extreme close-ups).

Just as dimensions are standard in nature, as sometimes is behavior, so are dimensions standardized to a more primitive extent in modern civilization. Road markings and man-made structures can be used like giant yardsticks.

Focus can be gotten by measuring it. There are the old established ways with tape measures. There are a few newer electronic methods and aids. They often prove cumbersome and not worth the time or expense. But even with the old workhorse tape measure, there are ways to streamline the process. We'll look at focus circles as they apply to the priority of mark getting. This discussion is especially pertinent in operator-assisted focus, where getting the fewest marks fastest can be very important to a busy assistant.

Eye focus can be assisted by a second assistant and/or an operator or not. Eye focus is affected by a number of factors. There are psychological, neurological, and physiological variables that contribute to limiting the eye's ability to attain sharp focus. This is why there are times when more than one method of attaining focus is advised. There are also times when two methods of judging focus may disagree. When that occurs you must know which method to rely on. If not, you can turn in an entire day of soft footage and have pulled to every mark "dead on." Hard to believe? It's been done and on big shows. I know of some very experienced DPs that get the answer as to which method to rely on 180 degrees wrong. But you're learning certain physical/optical facts here. You'll have enough confidence to stand your ground and argue your case. You'll turn in good stuff, and you won't get fired because some boss intimidated you into making his mistake. Right or wrong, who do you think they fire for out-of-focus dailies? But who do you think feels they have the right and position to tell you how to get focus, which is your job? That's right! It's your job, so protect it and don't let someone else tell you how to do it.

We'll look at specialty focus systems: electronic range-finders and computer-assisted systems that come with their own crew. You should know about them to know when to recommend them. And yes, focus pullers, they do have their applications.

Once you've gotten focus, you'll look at the best ways to make marks on the land (set floor) and "see" (lens or focus disk). You'll learn how to distinguish marks that can easily adapt to changing start and

end marks. Directors/cameramen are famous for this. We'll examine how to make confusion-free marks for complex camera moves. This will include possibly the most difficult moves: circular dolly track with ECUs. Marks and focus for crane moves, which are extremely difficult and complex, will be explained. This is truly focus in three dimensions. How do you distinguish coming from going? What if mark #4 is the same as mark #2, but only sometimes? We'll look at focus pulling: the best ways and sometimes not the best ways, but the way it's got to be, anyway. There are different situations that call for different techniques. Some border on the realm of tricks. Some aspects are very specialized.

Once you've made the shot, but before you can move on, you must be able to tell if you've got it. You must be able to assure some "keepers." There are okay ways to do this, and then there are better ways to do this. So let's start in the process of shot making: getting focus, making marks, and pulling focus.

Establishing Focus (Before)

Estimating Focus

Estimating is a crucial function of your job. Imagine you are pulling focus. You are constantly estimating an object's distance from the film plane and comparing it to the object's predicted distance from the film plane. This corresponds to the object's path along its predicted set of marks, placed on a follow-focus disk or lens. But before you get to making the shot and pulling focus, before you have made marks, one of the ways to get focus originally, besides measuring or eye focus, lies in the art of estimating distances. This can be one of the fastest and most efficient ways of getting focus, or marks, if done well. The process is even elegant in its simplicity. Before pulling focus, before marks, even before you are a working assistant, you can go a long way in this skill by practicing indoors or outdoors in a field.

Anato-metric Estimation (Extreme Short, Short, and Medium Distances)

Certain constant dimensional relationships exist in nature and in the body. If you're doing "tabletop" product shots, the distances are of course small. The distance from your elbow along your forearm to your fingertip is very handy. It is called a cubit. It is one-half the distance from the tip of your nose to your fingertip. Also handy is the distance between the tip of your extended thumb and the tip of your little finger. This dimension is usually 9 inches for the average man, 7 inches for the average woman.

The length of a person's arms, longest fingertip to longest fingertip, is almost exactly the same, to the inch, as one's body height. This is equal to twice the distance from one's nose to the longest fingertip. Learn the length of one arm, from the shoulder joint to the longest fingertip. Learn the distance across your shoulders from joint to joint. These give you four quick but very accurate measurements/estimates. Another quick focus estimate is to hold your hands out from your sides belt-high. Sight down your arms. Your body is describing a triangle, and the spot you are looking past your hands to the floor at is approximately the same distance away from you as your eye height is from the ground. This can be used to double-check your arm measurement, described earlier.

Learn the length of your stride. You're indoors and it's crowded, or you're outdoors and a lot is going on. Take a walk around the set; a tape measure would just get in everybody's way, maybe cause an accident and hold up work. You may look at ease, but you're measuring and studying the set and your shot. And you're staying out of other people's way while they work. Few people have done more than merely consider in passing the length of their own stride. When asked, most people overestimate its length. One reason may be lack of clarity as to what a pace consists of. Most people think of a pace as extending from the heel of the rear foot to the toe of the front foot. It sounds right at first. But if you use this criterion to measure multiple paces, you will have subtracted the length of one foot by including it twice, for each stride taken, after the first. To see this, imagine the first pace, then the second. The "front toe" foot of the first pace doubles as the "rear heel" foot of the next pace. A pace extends from the heel of one foot to the heel of the other, or from toe to toe, whichever is appropriate.

You can concentrate and measure your ordinary pace, but for men and women, the average pace yields unwieldy numbers. Unlike other body dimensions, a pace varies greatly among individuals, even of the same height. From this we are warned not to assume someone else's paces through a set that we are watching are telling us the same thing that our feet might tell us.

Learning and developing a special stride will create a "learned" pace that can be executed and repeated quite reliably. This new stride is usually achieved by stretching one's natural pace a little bit, as opposed to shortening it. How many of your paces fit into 10 feet or 12 feet, or even 60 feet? This is a fast, clean, and effective way to go. How long is your foot? Learn it to double-check short distances. These are excellent hands-on techniques for distances close in. Now let's extend things a little farther.

Trigonometric Estimation (Short and Medium Distances)

Close-in distances, beyond arm's reach, can be directly observed by borrowing a few basic tenets of trigonometry. Don't worry, I've already done all the math. One of the practical applications of trigonometry is finding the distances of inaccessible objects. Object distances beyond our reach fall into this category.

From plane trigonometry and the angular mechanics of three right triangles as they relate to the human body, we get methods for estimating distances from 6 feet to approximately 20 feet. While I'm the one estimating and approximating, I'm going to use my own eye height. We'll let that value form the altitude of a triangle. The two remaining legs, the hypotenuse and base of the triangle, extend from our eyes and from our feet to intersect in one of a triangle's three vertices. The distance from our feet to this vertex, or measurement of the base of the right triangle we form with our body, is our desired object distance. On a lens this is the focus distance.

An advantage of this technique, beyond giving a set of solid measurements, quickly found, is that it provides a method of double-checking close-in estimations made by visual sight memory. It also provides departure points for estimating intermediate distances, not given exactly by the three triangle functions. This range of 6 feet to 20 feet also covers the "most used distance areas" in complex blocking, found in dramatic production. These areas may be thought of in terms of "focus circles," shown later in this book. Now let's look at the three triangles.

45°, 30°/60°, and 15°/75° Right Triangles

First, the simplest and most uniform: the 45-degree right triangle. A right triangle contains one angle of 90 degrees, and the sum of all its angles must equal 180 degrees. If one remaining angle equals 45 degrees, so must the other equal 45 degrees. Since this triangle has two equal angles, it also has two equal sides. The third side is the longest side, because it is opposite the largest angle. The side opposite the 90-degree angle is called the hypotenuse. This is an isosceles right triangle. According to Pythagoras, the square of the hypotenuse is equal to the sum of the squares of the other two sides:

$$C^2 = A^2 + B^2$$

If $A = 1$ and $B = 1$, then C is equal to the square root of $1^2 + 1^2$, which equals the square root of 2, or 1.4142.

So imagine yourself as one leg of an isosceles triangle.

My eye height is 5′5″.

45° Right Triangle to Find ≈6 Feet and ≈8 Feet:

1. Look straight down at the point on which you stand.
2. Look straight out ahead of you. You are looking 90 degrees up from the previous point you spotted. You are looking at infinity.
3. Orient your line of sight halfway between these two points. Your line of sight is now bisecting the original 90 degrees. It describes an angle 45 degrees up from the point on which you stand. (This angle can be found quite easily with your eye/brain/body.)
4. Sight a point on the floor that is intersected by your line of sight. Your body and line of sight describe an isosceles right triangle. Remember, the sides opposite equal angles are equal sides.
5. The sighted point on the floor equals your eye height. It is as far away as your eye is high. If your eye height is 5′5″, your sighted object focus point is 5′5″ away.

TO FIND ≈8 FEET:

1. Extend your hand, at arm's length, out in front of you, so your arm is level. Find the point on the floor that you are holding your hand over. For my body dimension, this is 2′ from my body. You can measure from the inside of your shoulder, where it meets your chest, to your fingertips.
2. Step forward to place your toes on this mark. Look straight down at this mark. Maintain an idea of your original standing position.
3. Look straight down at the mark.
4. Look straight out. This, again, is 90 degrees up. You are looking at infinity.
5. Orient your line of sight halfway between these two points. This can be found by sighting straight out, then down repeatedly and swinging your head and sight line through an arc. You will get a feel for the location of the halfway point between the two sight lines of 90 degrees and 0 degrees.
6. The point on the floor you are now looking at is equal to your eye height plus your arm's length (inside shoulder). If your eye height is 5′5″ and your arm's length is 2′, the object focus point is 7.5′ from your original mark. Adjust your sight (estimate) and call it 8 feet.

30°/60° Right Triangle to Find ≈10 Feet and ≈12 Feet:

TO FIND ≈10 FEET:

1. Look straight down at a point over which you stand.
2. Look straight out at infinity.

3. Lower your line of sight 30 degrees, or raise it 60 degrees from straight down. Either lower your sight line one-third from straight out, or raise your sight line two-thirds up from straight down. Again, use your eye/brain/body to do this.
4. Sight a point on the floor that is intersected by your sight line.
5. Your body forms the altitude, and your line of sight is the hypotenuse. The length of the base equals the object distance to the object focus point. The length of the base is the square root of 3 multiplied by the altitude. If the altitude is 5′5″, then we have 5.42 times the square root of 3, or 5.42 × 1.7320 = 9.38′, or just over 9′4.5″. Call this 9.5 feet. Adjust your sight (estimate), and call it 10 feet. (Remember, we're estimating.)

TO FIND ≈12 FEET:

1. Extend your hand at arm's length, at shoulder height, out in front of you so that your arm is level. Find the point on the floor that you are holding your hand over.
2. Step forward so you can look straight down at this mark. Place your toes on this mark. For my dimensions, this is 2′.
3. Look straight down at the mark.
4. Look straight out at infinity.
5. Orient your line of sight down 30 degrees. This is one-third down from straight out.
6. The point you are looking at on the floor is 11.5′ away from your original standing location. Adjust your sight (estimate) and call it 12 feet.

15°/75° Right Triangle to Find 20 Feet:

1. Look straight down at a point over which you stand.
2. Look straight out at infinity.
3. Tilting your head down, lower your line of sight 15 degrees. This translates to about 1.5 or 2 inches of head movement.
4. Sight a point on the floor.
5. The point on the ground you are looking at is 20.5 feet away. Adjust your sight (estimate). Call it 20 feet.

You can now quickly determine and even pull focus to 6 feet, 8 feet, 10 feet, 12 feet, and 20 feet. This is before a single measurement is made. From these you can also find, quite quickly, 15 feet and 25 feet just by estimating off the original triangulated distances. These are very common focus distances found on lens etchings. They also provide a way to double-check distances that are raw estimates, found by visual sight memory (what a distance looks like).

These distances cover the most used distance areas in complex

blocking found in dramatic settings. Combined with the depth-of-field characteristics of lenses of certain focal lengths, set at certain parameters (lens focus and T-stop), this "close to intermediate" focus range creates zones of focus, which fall into great circles. These depth-of-field zones may be thought of as radiating out from the film plane. See Figure 2-1. We'll discuss these focus circles in greater detail later, when we talk about getting marks. Now on to bigger and better things, or at least longer distances.

Intermediate to long-range distance estimating, from 50 feet to 300

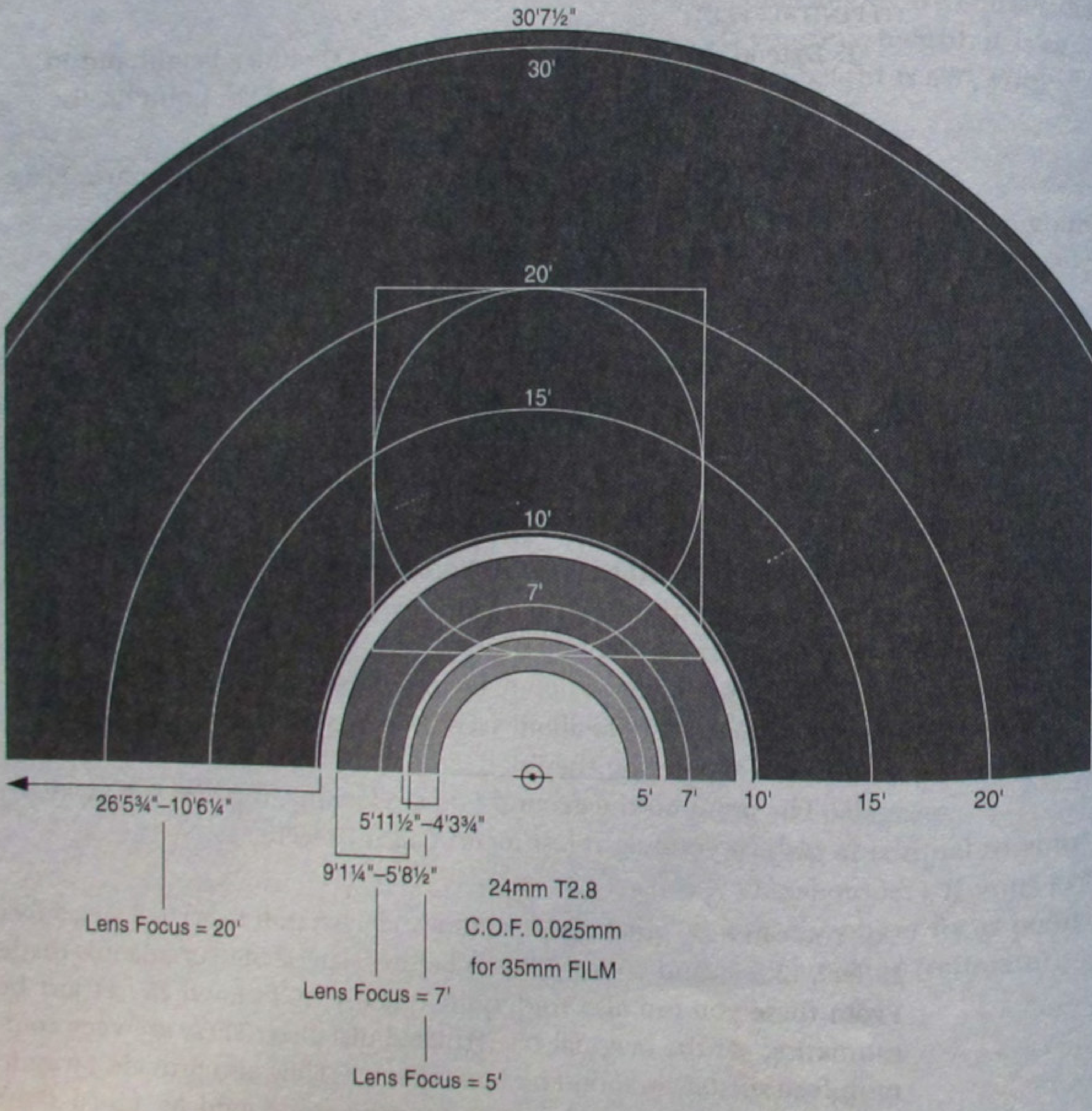


Figure 2-1a. Focus circle.

feet, is the outside edge of the envelope, due to parallax and distance compression problems. I consider these medium to long-range distances. Zero to 50 feet, we'll discuss last, because it is the easiest. Because it is close up, the distance intervals appear larger. With greater size comes more information. These distances can be found without visual aids. Instead we'll use what I call visual sight memory. It is merely remembering what a chunk of distance looks like.

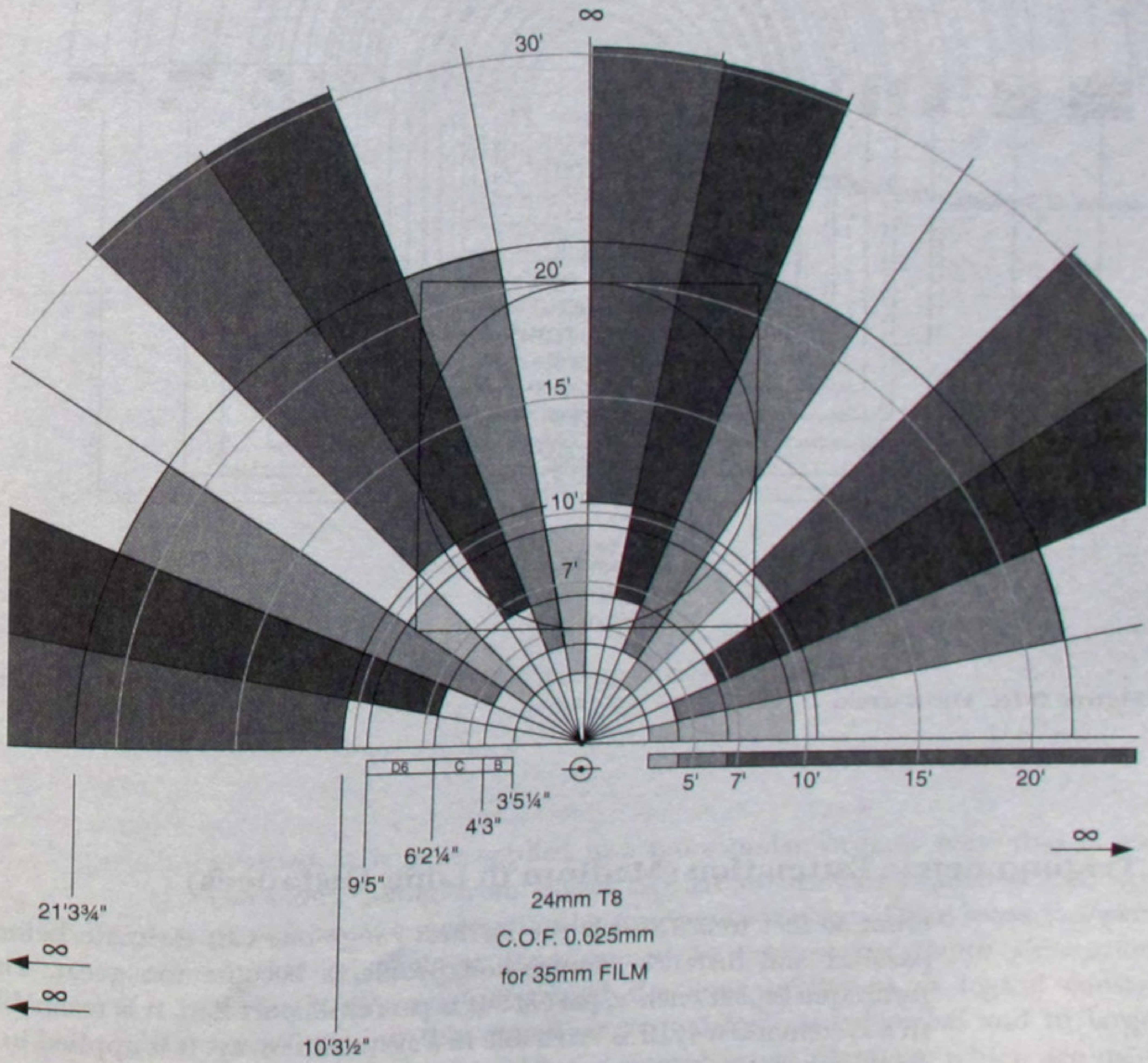


Figure 2-1b. Focus circle.

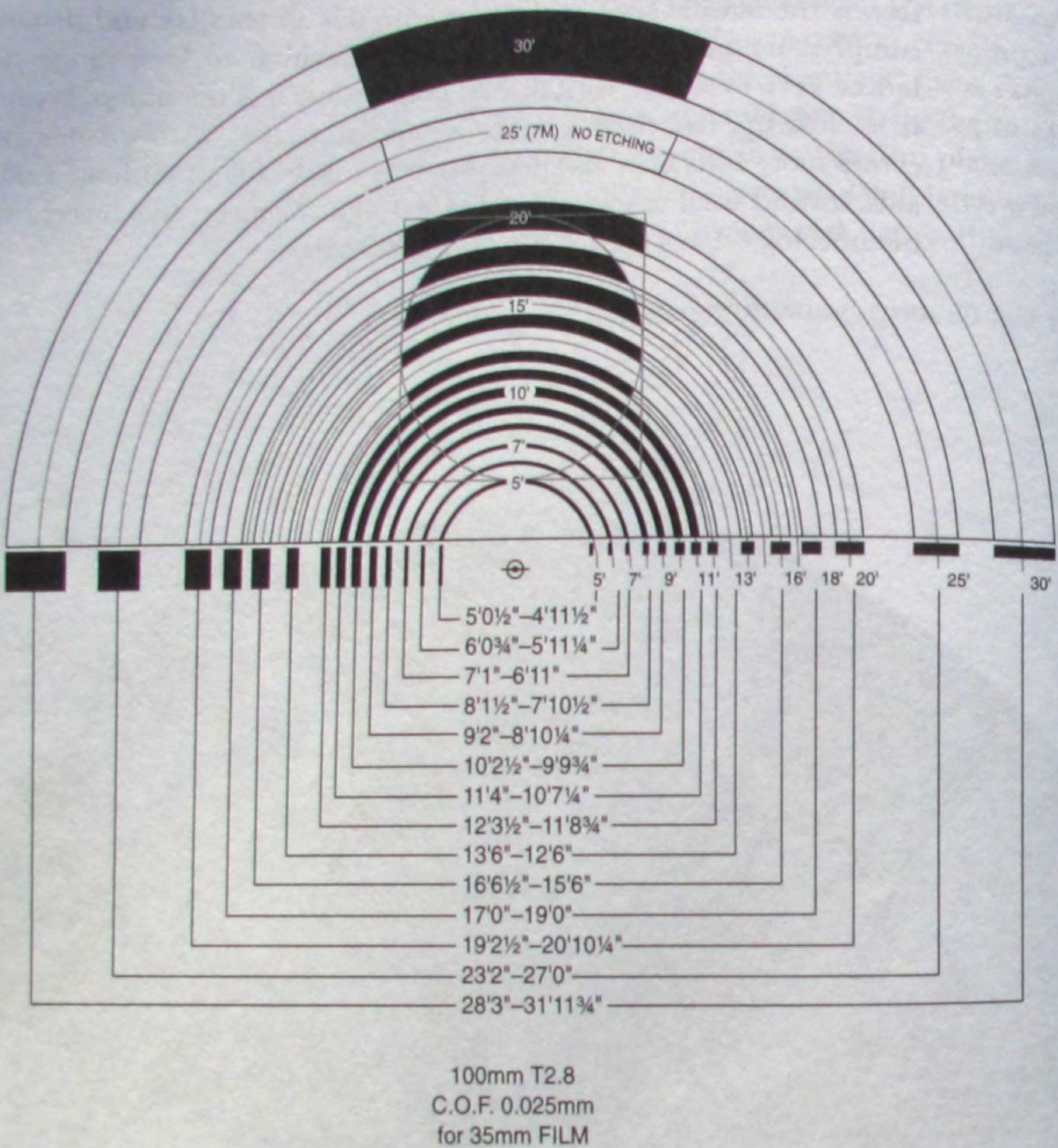


Figure 2-1c. Focus circle.

Trigonometric Estimation (Medium to Long Distances)

From 50 feet to 300 feet is the farthest range one can estimate before parallax and distance compression problems become too great. The technique is part science, part art. It is part skill, part Zen. It is teachable in a systematic way. It is learnable in a systematic way. It is applied in a more organic or Zen way. When it is first learned, it is used in a more systematic/skill way that is very conscious. As it becomes more in-

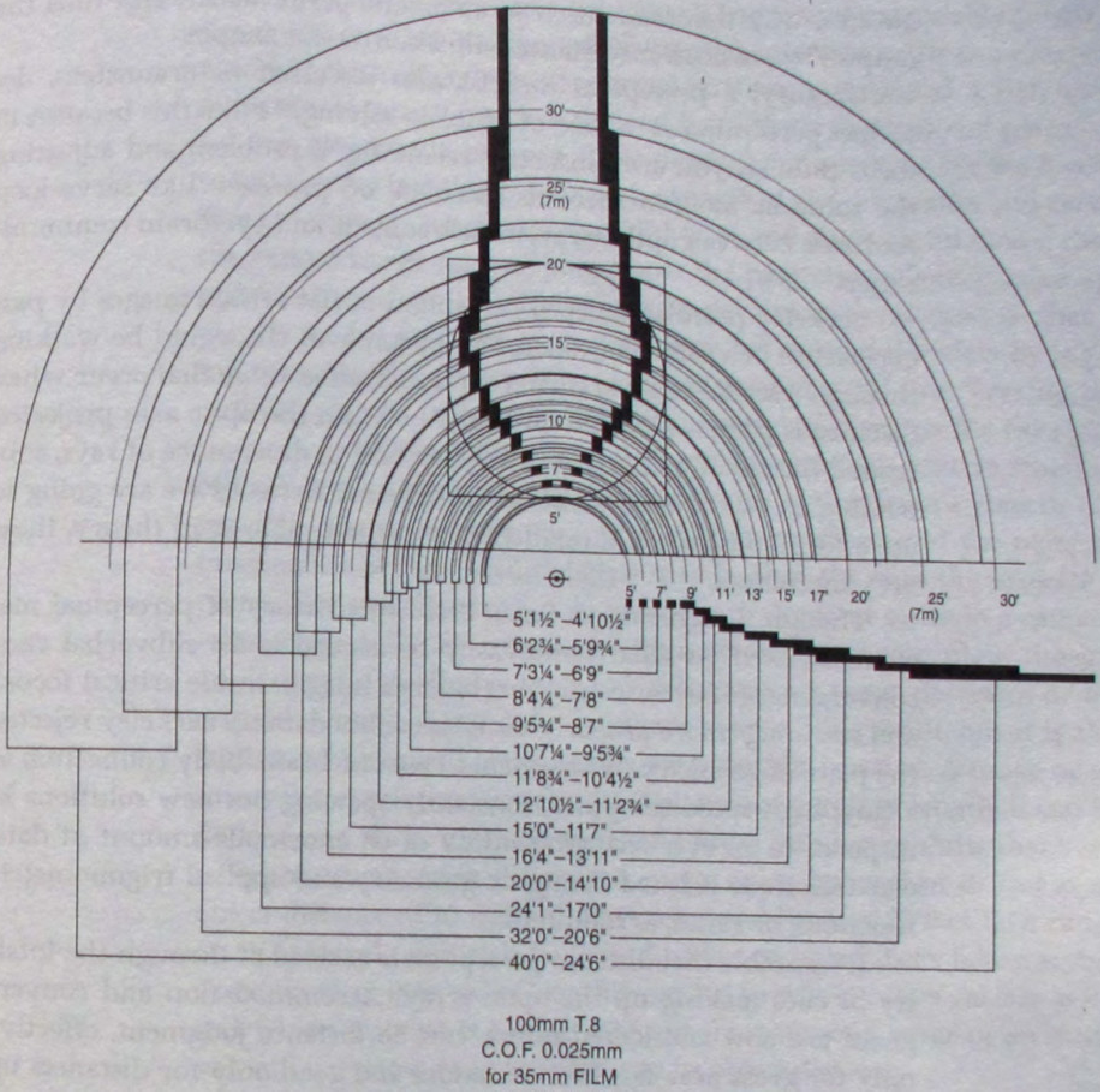


Figure 2-1d. Depth-of-field zones for various lens focuses, 5′ to 30′.

grained, it will be applied in a more molar, organic way, that is less conscious. Going from object sighted to distance estimated will approach an automatic stimulus/response paradigm. From sensation/perception psychology, Dees, quoted in Braunstein's *Depth Perception through Motion,* "questioned the appropriateness of logical consistency," stating that "most perceptual logic is subverbal and in large measure, automatic and based upon learned premises, which are usually true."[1] Cognitive processes are so complicated that they must oper-

ate in a way that lends itself to automatic performance, and thus the output/result/answer (distance estimation) seems simple.

Gregory, a perceptual theorist, also discussed in Braunstein, describes perception as "a kind of problem solving."[2] I like this because, in focus pulling, you are constantly rerunning a problem and adjusting the solution. Modern theorists speculate on processes like servo-loop feedback between optic array, muscle control, and eye-brain communication.

Berkeley postulated depth perception of flat retinal images by past experience of vision and touch. One example of this could be walking through a set. He negated subverbal cues, such as those that occur when distance is perceived, based on angles between the optic axes projected from a fixated object, as well as the decrease in divergence of rays, subtending an object as object distance increases. Actually we are going to use a form of distance estimation that partially shares, in theory, these very mechanics.

Though disagreeing in form, Berkeley's theory of perceptual mechanics rested on what could easily be argued to be subverbal cues: convergence (of eyes), confusion (blurred images, inside critical focus), and straining (more properly visual accommodation). Berkeley rejected the place of geometry in his scheme. I see our brain/body connection as a tiny, high-speed computer, constantly spewing out new solutions in response to an ever-changing influx of an enormous amount of data. Our technique is based firmly on geometry and applied trigonometric functions, or ratios, as solutions.

It's possible that distance perception is arrived at through the totality of cues making up the optic array. Accommodation and convergence are now considered minor cues to distance judgment, effective only for gross near-far discriminations and good only for distances up to several yards. Binocular disparity has been added to cue theory and the interaction of the above three cues has been added to directional muscular feedback-outflow theory. These are internal, nonlinear, organic processes. We will learn a process that is external, linear, and inorganic in its development. Judging object distance and describing size perception over distance mathematically will show the same perceived interval of length at increasing or decreasing distances to change exponentially. This means that a unit of length at twice a given distance appears more than twice as small. This technique should be added to the total impression formed by the optic array. Other cues making up the optic array include brightness and atmospheric attenuation. These last two cues may contain misinformation and thus are possibly misleading. This is because the brain tends to make certain assumptions despite veridical reality and has been shown to make wrong decisions. The

brain's seemingly subjective behavior is more understandable when it is pointed out that its final physio-spatial interface with the external world is the retina. Onto its curved surface is projected a flat, two-dimensional image, which is derived from three-dimensional space.

Can we visually perceive three-dimensional space, or are we forced to just assume it is there? Let's look at some of the mechanics and relate them to distance estimation. A useful term and more useful model than the retinal image for our purposes is the projection plane. It is an approximation described by Leonardo da Vinci. He suggested that a painter imagine a plane of glass between his eye and the view he is going to paint. The glass is perpendicular to one's sight line. Tracing the outlines of light rays emanating from a scene or object as the rays pass through or intersect the glass will show approximate relative amounts of the retinal surface struck by light rays projecting from a view or object. The image on the retina or glass is a projection, and the plane of intersection of rays with the glass may be thought of as the projection plane. This can also serve as an analogue to the focal plane in a camera, where hopefully sits a frame of film. On the projection plane, images get larger or smaller as their object distance or range decreases or increases. A range is not only a distance to an aiming point, but it is also "the class of admissible values of a variable,"[3] or interval. A range or an interval can refer to near and far distances of a unit of length; it can be defined as a finite distance, made of a finite number of units that vary in apparent size with distance. A range or an interval of 10 feet at an object distance of 10 feet will have a far end limit of 20 feet. So a range or an interval may itself be thought of as an object. Let's take another example of an interval of length from 200 to 300 feet. Interval size is 100 feet. Object distance is 200 feet. The apparent size of a range or an interval will vary inversely according to its object distance.

In the field of sensation/perception, an experimental branch of psychology, it is maintained that "the dimensions of an object's representation on the projection plane are determined by a combination of factors: 1. Its dimensions in three-dimensional space, 2. Its orientation to the observer, 3. Its distance from the observer."[4] See Figure 2-2.

For focus pullers, I want to emphasize this third factor. Dimension and orientation are important considerations in any distance estimation, but this third factor, distance, is a keyword in distance estimation, and it is a key variable, because key to focus pulling is judgment of object distance.

Distance: (Oh no! Not more definitions!) Think of it as a tool to use. Isn't tool use what separates monkeys from lower animals?

"Distance: 2a. A portion. b. The degree or amount of separation between two points, lines, surfaces, or objects in geometric space, meas-

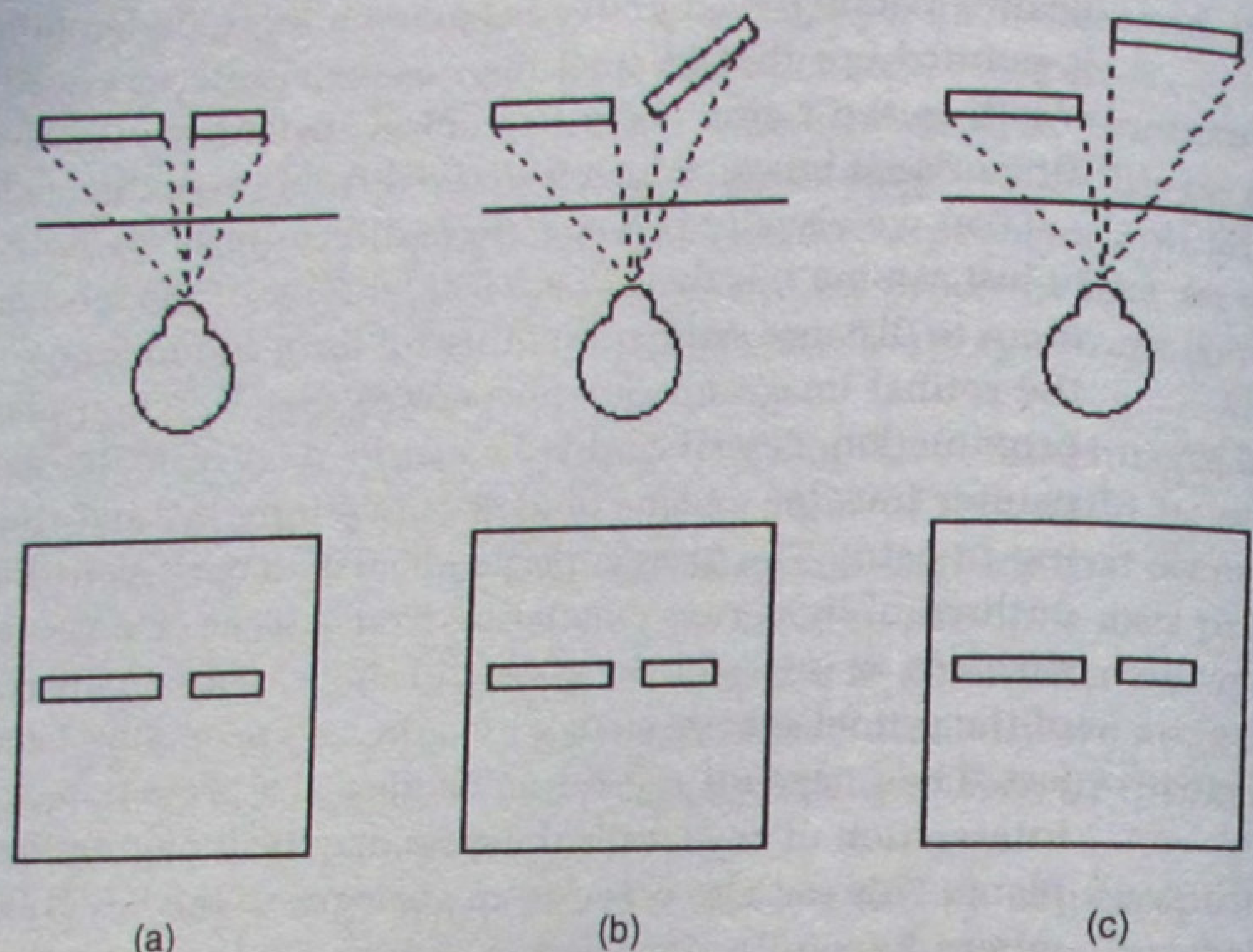


Figure 2-2. Objects are perceived according to their (a) dimension, (b) orientation, and (c) distance.

ured along the shortest path joining them. 3. The amount of space between the eye and an object of perception... c. The extent of space measured linearly along a route: the length, especially of a surface or road traveled or to be traveled (to be traversed by you, a second assistant, and of course, light rays)... e. A portion viewable all at once... 4b. Perspective."[5]

"Distant: 1a. separated away in space. b. separated by intervals of greater or less regularity."[6]

The relationship between distance and dimension will seem at first too obvious. And you might ask why concern ourselves at all with dimensions, when it is an object's distance, not an object's dimensions, which will never be the same. People and things come in an infinite number of sizes, so this can never serve as a clue to their object distance, which will determine their focus at the film plane. To an extent this is true, but there is one object that can be standardized, and that is a range or an interval, composed of a finite number of units of length. Remember, a range or an interval can be thought of as an object. We will use a model of range or interval size to show that, as you learn to estimate distances, you must keep in mind that the change in apparent range or interval size with distance is exponential, not linear. This

means that 10 feet at 20 feet does not look the same as 10 feet at 30 feet. And 10 feet at 40 feet is not 50 percent the range size of 10 feet at 20 feet. It is apparently only about 30 percent as big: 10′/20′ = 4° 58′, 10′/40′ = 1° 33′. Sometimes 50 feet at 100 feet looks the same as 100 feet at 200 feet, but sometimes it doesn't. The reason such relationships appear to be linear (similar ratios–similar angles vs. similar ratios–dissimilar angles) lies in a trigonometric parity of two legs of a triangle measured and combined in a function to reveal the subtending angle, for us a vertical or range angle. For you this means that an object at 100 feet does not look twice as far away as an object at 50 feet. In fact it looks only a tiny bit farther. And starting with a vertical angle of 90 degrees being infinity, and 0 degrees being 0 feet at your toes, an object distance of 300 feet subtends a vertical angle/range angle that is only a tiny percent smaller than the vertical angle subtended by the same object at infinity!

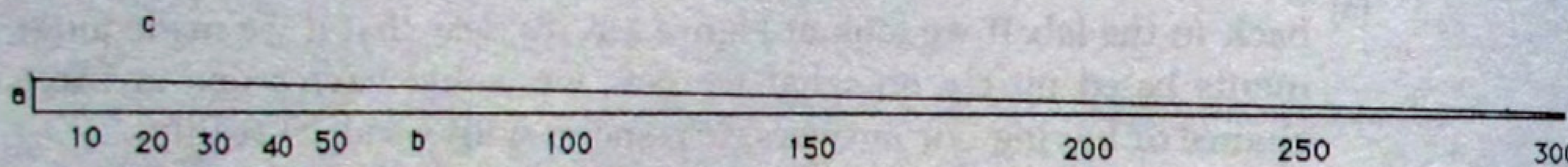
We're now going to forget about what we think we see and instead know what we see. Pretty Zen, huh? To me, it is a quite Zen concept that some consider science to be the business of discovering God. So, back to the lab. If we look at Figure 2-2, it's clear that if we made judgments based purely on what we saw, we would have a one in three chance of having our answers correspond with veridical reality.

We might as well guess. Actually, there is a case to be made for guessing. It doesn't apply here, but later we will discuss the value of guessing in heuristic problem solving. Your brain will like it. It works that way a lot of the time. It's kind of a conscious use of the unconscious.

In Figure 2-2, projection (a) shows dimension. For focus pullers, there can be no standard dimensions of objects to be focused. Projection (b) shows orientation. Orientation can also be slant. Slant poses a special case and, as shown here, comes complete with its own misleading illusions. Incidentally, in our technique you will see that we always look at our world at a slant. Our technique, however, controls for this factor. It is this knowledge, in fact, that renders our solutions. We'll discuss how to factor in uncontrolled for slant later. Projection (c) exemplifies the basic tenet of our technique. If apparent range size is smaller, that interval is farther away. If the range size is of a known object, such as an interval of length, object distance can be found to be a simple trigonometric solution. The trick in distance estimation is to form a 90-degree angle to the ground with our body forming the vertical leg of a triangle. Our sight line (slanted) forms the hypotenuse of a triangle. That sight line intersects the base leg of the triangle at a point that is our object distance. To an object to be focused, the base leg dimension, or object distance, is the numerator of the sine function of the vertical angle, or range angle. The sine of an angle is the ratio of the leg opposite that

angle to the length of the hypotenuse. This is how the range angles for particular object distances were developed for this technique. Now if the tangent of an angle is the ratio of the side opposite the angle, divided by the side adjacent to the angle, and we know the length of the adjacent side (eye height) and our vertical angle, we can find the length of the side opposite. This solution is our object distance, and it indicates the focus distance (lens focus) mark to be set on the lens. See Figure 2-3.

The figure is a model of the preceding description. It shows the problem we face as humans standing on the planet. Basically, in the cosmos, "man" is too small. This is why 300 feet is about the outside of the distance estimating envelope. We're just too close to the earth. Beyond 300 feet, angle change with distance is so negligible (rapid deceleration) that angles become effectively parallel angles. This is what we find at infinity. This is where parallax and distance compression pose prob-



Hypotenuse is c.
Vertical leg is a = 5′5″ (eye height).
Base leg is b = object distance.

$$\tan = \frac{\text{opp}}{\text{adj}} = \frac{\text{object distance}}{\text{eye height}} = \frac{b}{a}$$

so $b = \tan \angle b$ (vertex angle) $\times a$

so object distance = $\tan \angle b$ (range/interval angle) $\times$ eye height

Ex: Take object distance = 50′
Eye height = 5′5″

$$\text{In } \tan \angle b\ (83^\circ\ 48') = \frac{\text{opp}}{\text{adj}} = \frac{\text{object distance}}{\text{eye height}}$$

$\tan 83^\circ\ 48'$ = 9.2052 $\times$ 5′5″ (5.466) = 49.861499
(vertex angle) = (tan function [see table]) $\times$ (eye height) = (object distance)

Then

$$\text{tan of vertex angle (b)} = \frac{50'}{5.4666} = 9.2307 \approx 9.2052 = 83^\circ\ 48' \text{ (trig table)}$$

Figure 2-3. Theoretical model for distance estimation.

lems that are too great. To see this, look down at the surface of a table. Now lay the side of your face on the table and look across the surface. We are indeed small creatures on the planet. At 300 feet, the information in the optic array is greatly reduced. The greater the distance, the smaller the angle. The smaller the angle, the less information. The less information, the greater the chance of inaccuracy. The brain has two very distinct tendencies to guess relative distance and absolute distance, based on its own, and often very errant, set of criteria in a visually reduced environment (Gogel 1973a,b).[7] So forget trying to tell how far away things are by how they appear. At great enough distances, you can't even tell which of two objects is farther away. Your brain will think it can and will probably get it wrong. However, there's a way to overcome this to a great extent. We'll discuss this later in a catch-all section on focus aids and tricks.

So back to Figure 2-2, projection c, and a quote: "The effect of the distance between the observer and an object on the dimensions of that object's projection is a perspective effect. In general, perspective refers to variations in a two-dimensional scene that reflects relationships in the third dimension."[8] In considering the X axis as width (not a consideration for us), your body forms the Y axis, and the object distance lies along the Z axis. Perspective, a definition: "1a: The technique of representing on a plane or curved surface, the space relationships of natural objects as they appear to the eye.... 4. The appearance to the eye of objects in respect to their relative distance and positions."[9] This last quote, taking applicable definitions of perspective into consideration, means that in looking at an object distance, and estimating any distance, that interval or range, as it appears on the projection plane is undergoing a constant change, over its entirety. This is due to the effect of perspective, which is constantly interacting with an object's image projection from proximal point to distal point, and vice versa. As an interval recedes from you, it is appearing to shrink at a rapid, yet decelerating rate to infinity. This change in apparent range size is gradual. It is known as a perspective gradient. It is an important concept in understanding the apparent vanishing of lines and dimension at an exponential rate over the course of linear increase in object distance. Humans perceive texture gradients and use them to judge distances in everyday life. Look out over a choppy sea or a large field of grass. The perceptual effect is due to an apparent or real variation of size and spacing of surface features. A mirage on a highway is related to this perceptual process.

For our technique, which must be completely regular in its use of surface features to ensure reliability in its performance, we will take advantage of a special case of texture gradient. This is the cue of linear

perspective. Linear perspective occurs when we look at the ground plane over which object distance extends. It is one plane of an infinite number of planes in our effective optic array. We view it at a slant. Our sight line to the distal point of our range or interval at object distance forms the slanted hypotenuse of a right triangle. Our body forms the vertical leg. Obversely, the ground plane or object distance can be considered at a slant to our line of sight and to our body. Imagine two parallel lines are present in some plane of our effective array. Let's imagine that the two parallel lines lie in the plane of the ground plane and extend away from us toward the horizon and infinity. These lines appear to us on the projection plane to be converging. This is the effect of perspective on distance that is experienced as linear perspective occurs. It can also be said that this is the effect of real distance on linear perspective and of linear perspective on apparent or perceived distance. Measuring the separation between these lines on the projection plane, over distance, reveals a decrease that is systematic and forms part of a continuum. This systematic, continually decreasing value constitutes a gradient.

Figure 2-4 is a graphic representation of linear perspective as described above. If you were to graph the values for interval size over distance, you would get a curve much like that shown in the figure. This is the same curve that can be derived from the density values of a texture gradient. Texture gradients will not concern us, nor will line separations. But if instead of width (X axis), we look at length (Y axis), we will see that a similar exponential relationship holds for apparent range size over distance. Remember that object distance lies along the ground plane and that as we stand at zero distance, the determining value of object distance is the intersection of the ground plane and the hypotenuse of the triangle, which is our sight line. The triangle is completed with our body standing at zero units of object distance and forming the vertical leg of the right triangle.

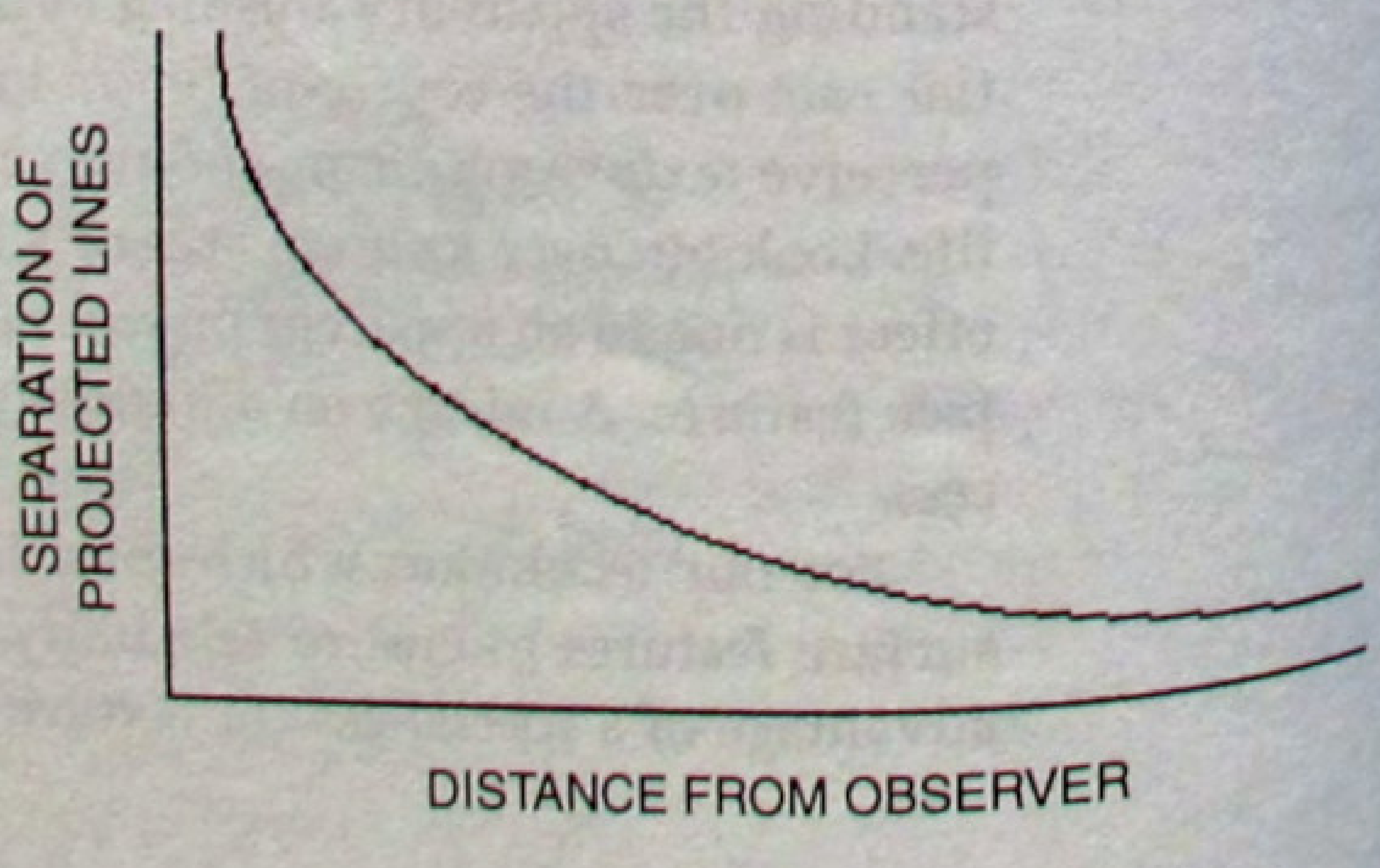


Figure 2-4. Parallel lines receding from an observer appear to converge. This effect is exponential (nonlinear), as shown by the decelerating curve.

So in distance estimation, rather than using two lines of separation on either side of us, we will look at one line that extends away from us toward infinity. We will use its apparent length to get a feel for estimating distance. The same foreshortening occurs over distance along the Z axis as it does along the Y axis (graph of separation gradient) at the very same rate. See Figure 2-5. In Figure 2-6, imagine you are looking straight down at it. The Y axis comes straight up at you. The X axis heads east and west. The Z axis heads north and south, pointing to 12:00 and 6:00 o'clock.

On the left, in (a), note the length of the arrow along the Z axis. See Figure 2-6. It is equal in length to the arrow on the X axis. On the right is the same grid tilted away from you 60 degrees. The arrow along the Z axis is the same length as on the left, but it appears shorter than the arrow along the X axis.

If you measure the vertical angle or range angle subtended by a fixed range or interval size as a function of distance and make a graph of it, it will reveal a curve that is almost identical to the graph of separation of two parallel lines that extend toward infinity. Figure 2-5 is a bar graph showing apparent decrease in interval size. The following tables show the data used to generate such curves. See also Figures 2-7, 2-8, and 2-9.

Table 2.1
Size of a 10-foot range/interval at 0 feet to 40 feet in degrees of vertical angle subtended

Eye height = 5′5″
Vertical leg (a = 5.4166666′)
10′/0′ = 61° 33′
10′/10′ = 13° 18′
10′/20′ = 4° 55′
10′/30′ = 2° 26′
10′/40′ = 1° 36′
See Figure 2-7.

Table 2.2
Size of a 50-foot range/interval at 0 feet to 250 feet in degrees of vertical angle subtended

Eye height = 5′5″
Vertical leg (a = 5.4166666′)
50′/0′ = 83° 48′
50′/50′ = 3° 6′
50′/100′ = 1° 0′
50′/150′ = 0° 30′
50′/200′ = 0° 18′
50′/250′ = 0° 12′
See Figure 2-8.

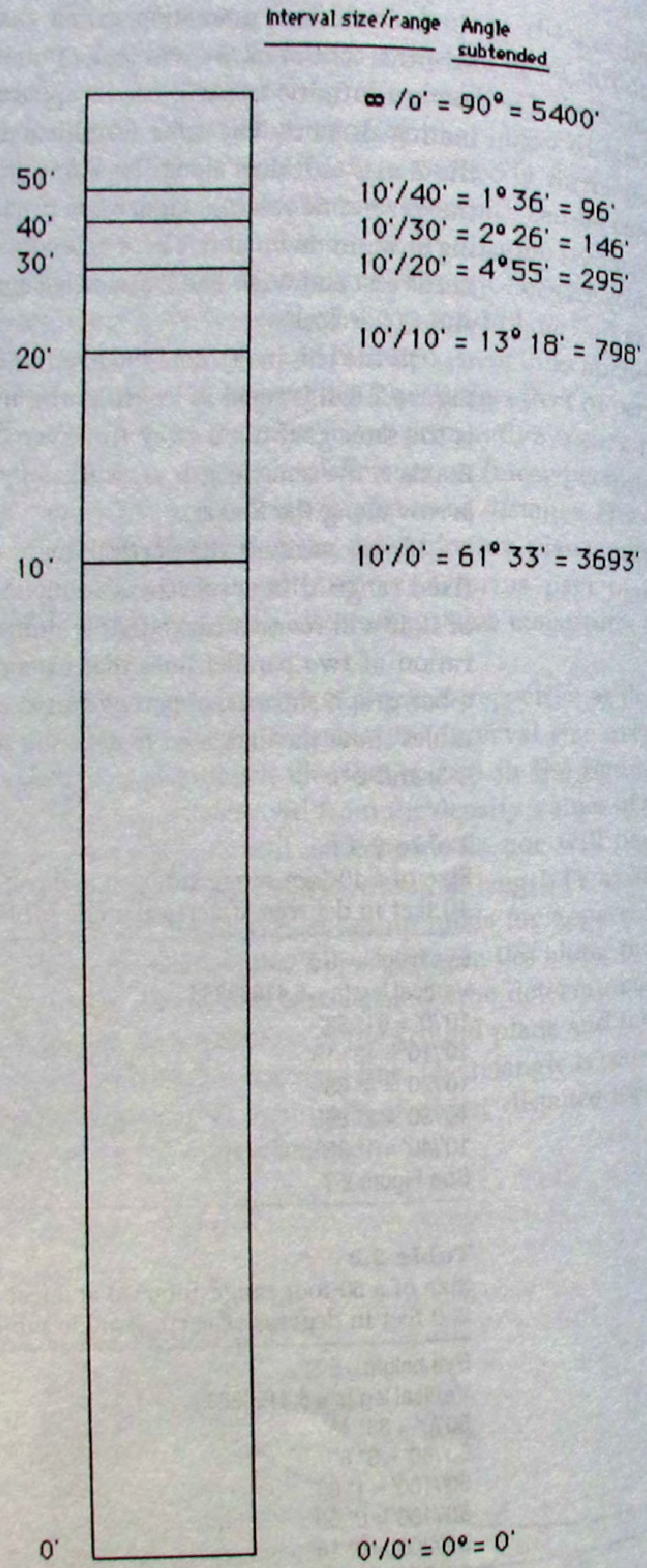


Figure 2-5. Perceived interval size decreases in unit length as object distance increases. The rate of change is exponential, not linear.

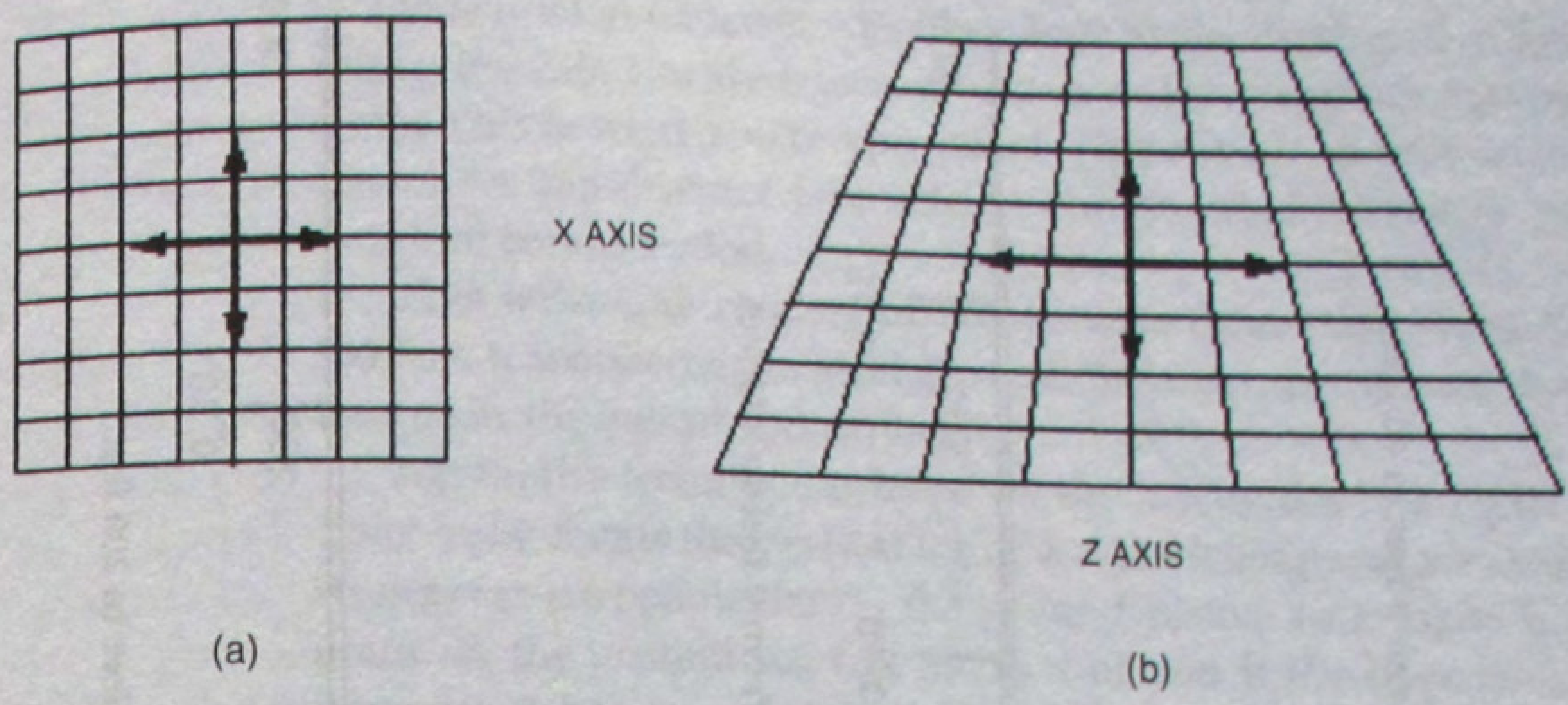


Figure 2-6. (a) Point of view above grid. (b) Grid is rotated about the X axis, the top moving away from the observer. The top of the Z axis arrow is farther away than is the bottom of the arrow. The Z axis appears shorter as it recedes and the object distance increases. The X axis arrow appears unchanged as all points on the arrow maintain the same object distance as in (a).

Table 2.3
Size of a 100-foot range/interval from 0 feet to 200 feet in degrees of vertical angle subtended

Eye height = 5′5″
Vertical leg (a = 5.4166666′)
100′/0′ = 86° 54′
100′/100′ = 1° 30′
100′/200′ = 0° 30′
See Figure 2-9.

On a bar graph showing the three selected range/interval sizes of 10 feet, 50 feet, and 100 feet, the longitude would be foreshortened over the distance of these range/interval sizes. It is the effect of perspective along the Z axis as the ground plane extends away from you.

On this range size bar graph there is distortion because infinity is artificially limited in order to see the end of the graph. In the natural world the end of the graph is at infinity and is therefore impossible to see. To make a representation of diminishing range size in a graph, one must place infinity at a finite distance. Also, range sizes in the real world are viewed from certain heights (vertical legs of triangles). No vertical leg is known, so range/interval size relationships are found arithmetically, without trigonometry. This means that while an angle subtended by a certain range/interval is a certain percentage of 90 degrees, that same angle cannot be discerned as a percentage of infinity.

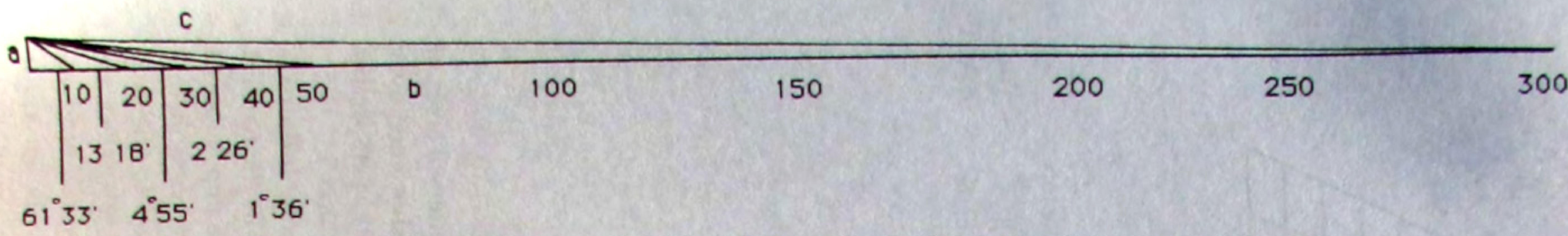


Figure 2-7. Subtending sighting angle change with object distance for 10-foot intervals from 0 feet to 40 feet.
Hypotenuse is c.
Vertical leg is a = 5′5″ (eye height).
Base leg is b = object distance angle subtended by 10′ interval range from 0′ to 40′.

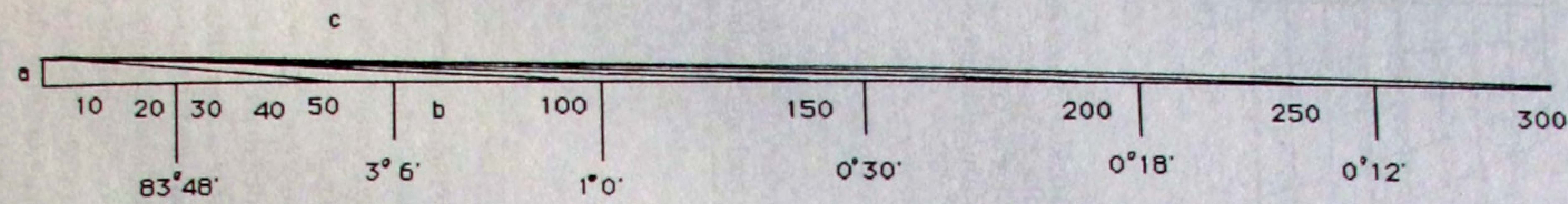


Figure 2-8. Subtending sighting angle change with object distance for 50-foot intervals from 0 feet to 250 feet.
Hypotenuse is c.
Vertical leg is a = 5′5″ (eye height).
Base leg is b = object distance angle subtended by a 50′ interval/range from 0′ to 250′.

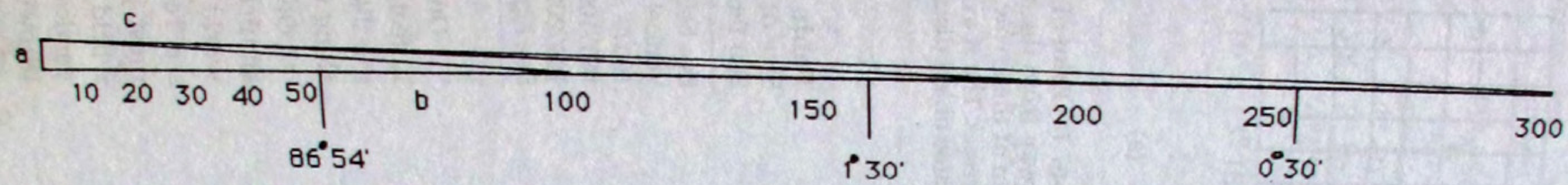


Figure 2-9. Subtending angle change with object distance for 100-foot intervals from 0 feet to 200 feet.
Hypotenuse is c.
Vertical leg is a = 5′5″ (eye height).
Base leg is b = object distance angle subtended by a 100′ interval/range from 0′ to 200′.

This is what happens when you look at the earth and objects standing on it while you are trying to estimate object distance and pull sharp focus. This is what you're up against. This is how to deal with it, or at least, here is a distance estimating technique that takes this phenomenon into consideration.

This technique renders object distance estimation from 50 feet to 300 feet. It is effective on level ground. Slant is a special case that will be treated at the end of this explanation.

Again, the technique is based on the mechanics of a right triangle. Your body forms the vertical leg of a right triangle, as you stand erect, 90 degrees perpendicular to the ground plane. Your sight line to the point on the ground 300 feet in front of you is the hypotenuse of the triangle. Where your sight line (hypotenuse) intersects the ground plane, it forms a vertex at object distance: 300 feet. As you look at this point on the ground, the angle formed by the intersection of your body (vertical leg) with your sight line (hypotenuse) forms a vertex subtending an angle of approximately 89 degrees. This is called a vertical angle, sighting angle, or range angle. Great, but how does your body distinguish 89 degrees? It can't—consciously. But you can learn to look straight out, dead level at infinity. And you can learn to look at your hand (if you're a smart monkey). And you can learn this technique at a conscious level. With practice you should be able to use the technique at a semi-automatic, semi-conscious level. Ideally, the process will become completely internalized and integrated into your senses and used in a purely organic way. This is where you want to get. To a good focus puller, a distance just feels like a certain distance. His brain, at some level, has not only already done the trigonometry, but it has processed a mountainous flood of complicating factors and data, the stuff of which fills experimental cognitive research journals in sensation perception psychology, which fill whole basements at UCLA. Phew!

Stand on the earth and look straight out. You're sighting infinity. Your brain/body interface can quickly learn this in only a few trials. To confirm it, use a string level or equivalent. Hold your fist at arm's length off the centerline of your nose. Point your thumb at infinity. Your sight line is level. Your fist (man or woman) subtends an angle of 10 degrees. Astronomers have been doing this for years. I've worked out my own eye height of 5 feet 5 inches. I'll show you how to plug in values and compute for your own eye height in the back of this book. (See Chapter 4, Infinity Bag.) Learning and practice are aided by the use of a small, clear centimeter ruler (marked in inches and tenths of an inch), held at arm's length. Again, the aim is eventually to use no artificial aids even with this technique.

To Look at 300 Feet for Eye Height 5 Feet 5 Inches: Hold out your fist, with thumb on top, at arm's length. Look at infinity. Sight line is level. Vertical angle is 90 degrees. Look down 1.1° (1° 6′). This equals .55″ (.5522) or approximately .6″ from the top of the thumb to the bottom of the thumb. You are sighting 300 feet.

To Look at 200 Feet for Eye Height of 5 Feet 5 Inches: Sight infinity. Look down from top of thumbnail 1.6° (1° 36′). This is .8032″ down from infinity. With your thumbnail pointing at infinity, let your sight line graze the top of your index finger at the second (middle) knuckle. You are looking at 200 feet.

To Look at 150 Feet for Eye Height of 5 Feet 5 Inches: Sight infinity. Check 300 feet. Move your sight line down 2.1° (2° 6′) from infinity. This equals just over 1″ (1.0542″). Your sight line will just bisect the second knuckle of your index finger. You are looking at 150 feet.

To Look at 100 Feet for Eye Height of 5 Feet 5 Inches: Sight infinity. Check 300 feet. From infinity look down 3.1° (3° 6′), or 1.6″. Your sight line will bisect the notch formed between your index and middle finger. You are looking at 100 feet.

To Look at 75 Feet for Eye Height of 5 Feet 5 Inches: Sight infinity. Check 300 feet. From infinity look down 4.2° (4° 12′) or 2.1″. Your sight line will bisect the third (distal for open hand; proximal for fist) knuckle of your middle finger. You are looking at 75 feet.

To Look at 50 Feet for Eye Height of 5 Feet 5 Inches: Sight infinity. Check 300 feet. From infinity look down 6° (6° 0′)or just over 3″ (3.012″). Your sight line will just graze the bottom of the third (distal) knuckle of your third finger. You are looking at 50 feet.

Like most skills, this medium to long-range distance estimating technique is easily taught and learned. Like other skills, the technique must be learned thoroughly before it can be used efficiently. This is because some of the processes involved exist at a conscious level, and some of the processes involved exist partially, if not completely, below a conscious level.

Learning it and practicing it occur in the same arena, or should I say football field? With its regular markings, a football field makes a perfect place to take theory literally out into the field and practice it empirically. A football field is conveniently 300 feet long. It is marked regularly. This will help you maintain accuracy as you lay out with tape measure, sticks, and flags your distances. Place a visible flag on a

stick starting 50 feet from the goal line. Place flags progressively at 75 feet, 100 feet, 150 feet, 200 feet, 250 feet, and 300 feet. Mark the appropriate distances on each flag. I use medium-weight kite sticks, available at the hardware store. I spear legal paper onto them. Not including the 75-foot mark, I recommend regular intervals of 50 feet. Homogeneity is a strong factor when judging distance in texture gradients, of which linear perspective is a special case. It allows you to compare interval/range size over distance. Remember, you can think of an interval of distance, or range, as an object and watch the effect of perspective on that object over distance.

Start with infinity. You can train your brain/body memory to sight infinity in only a few trials with the following device. It will also enable you to verify that you are holding your fist at a level sight line as you begin practicing. On a piece of dowel rod or kite stick about 3.5 feet long, place a string level about halfway along its long axis. Use heavy-duty sticks for this to avoid bending. This would make the level useless. In front of the line level, affix to the stick a mirror that can be angled back to your eye, so you can view the level. Mirrors mounted on swivels, like the kind bicyclists use, work well. Hold one end of the stick next to the orbit bone of your eye and lay the other end between your thumb and index finger. Make a fist and extend your arm in front of you toward the horizon. The distal end should lie in the vertical plane bisecting the bony mass of your nose. Sight along the stick across your thumb, adjusting arm height until the bubble on the level "trues" up. You're looking at infinity. Another handy tool is a clear six-inch ruler. You can double-check the vertical distance down from your thumbnail as it points to infinity. The vertical distance down gives the orientation and location of your sight line for any specific distance targeted. Eventually you should be able to discard the ruler and the level sighting rod as you become the Zen instrument.

To do it, you must do it. Over and over and over again! Long distance estimation is like blind pulling (focusing marks on a lens without looking) in that you must wade through some very ragged beginnings before the learning curve starts to steepen and those results sweeten up. When the curve begins to climb, it will accelerate swiftly and steepen sharply. When it begins to happen for you, the rewards, intrinsic and extrinsic, are substantial. Unlike blind pulling, you can try it at shoots even before you've mastered it. This is because this kind of estimating often occurs while a shot is being set up and the camera is off. Blind pulling occurs "in shot," and at $4,000 an hour, somebody else's shoot is no place to practice it, unless you don't like your job very much. So practice! During a setup the operator will often twist the lens to an eye focus and you can compare the result. So practice a lot, maybe for years,

and eventually, as it becomes internalized and organic, a given object distance (stimulus) will feel like a certain lens focus (response).

HEURISTIC PROCESSES/PROBLEM SOLVING FOR FOCUS

Just twist it! Heuristic processes in problem solving: an application for focus. It turns out your brain tends to use heuristic systems in processing visual information and solving perceptual problems. So this is a good place to mention the "hope you get lucky" lens twist, or the "heuristic twist." Because of your brain's tendency toward heuristic processes, I think it will like this one. First a definition. Heuristic: from the Greek *heuriskein* "to discover": providing aid or direction in the solution of a problem, but otherwise unjustified or incapable of just application.[10]

If you just grab a lens and twist it without thinking, is it unjustified? Maybe, but is it true you were not thinking? Maybe not. I've found, and other assistants have found, that this seemingly nonthinking twist to a focus often comes up remarkably accurate. At a level different than we consciously use, but at one our brains often operate on, thought processes of some form were going on. Heuristic attempts at solving a problem are those that go more directly to test solutions without all the data. Having all the data can ensure greater likelihood of a correct solution, but at a cost of greatly increased and possibly unfeasible time consumption. In short, your brain likes the idea of just jumping in and hoping you get lucky. You just might. Combining practice and internalizing of the estimating technique, shown earlier, with natural heuristic processes will yield increasingly sharp results. So like the tennis shoe people say, "Just do it!"

There is another edge to the heuristic sword. And it is the reason why the scientific estimating technique of knowing, not thinking, can save you from cutting your own throat. Producers love blood. Errant heuristic processes are seen in the brain's predisposition toward certain conclusions in relative distance and absolute distance judgment. Where visual information is reduced, objects in relation to each other tend to be judged as equidistant. In similarly reduced optic arrays, certain absolute distances tend to be attributed to certain objects and surface textures (Gogel, 1973a,b).[11] On the brain's part, these are assumptions. I want to stress that you should assume nothing, as does the estimating technique, which is rigorous and scientific. Think of or consider all available elements or features of the distance estimating environment. Don't let illusions or heuristic perceptual assumptions fool you, but

consider the weight of and use all informational factors in your environment. "The best explanation of findings in depth perception have been those that assume that perceptual judgments are based on the totality of information available in the optic array."[12] Expand your optic array. Adding the medium to long-distance estimating technique does just that.

Here is a short discussion of outside extremes of theory and special cases, such as focus with no landmarks in a featureless environment. Retinal gradient theories evolving to stimulus gradient theories explain perception along neuro-physical gradients. The natural extension of these theories would be ultimately being able to pull focus on water or on objects in midair, with no ground reference. Given the literature on visually reduced arrays, I doubt this level of ability could ever be attained, but it's interesting to think about.

The last special case: slant. The above technique assumes level ground. So, in that we don't always have level ground, it is reduced to a starting point. On sloping terrain, distances subtend angles of greater or lesser magnitude, depending on whether the terrain distally slopes up and away from you (uphill) or down and away from you (downhill). Slant cannot be accounted for handily with any kind of mathematical conversion of the earlier shown estimating technique. This is because slope will never be the same. It cannot be predicted or anticipated. Slope may even vary in the same distance continuum. Terrain can be undulating or may even appear broken, as with superimposition of hills in the foreground. Though slant often adds irregularity, each feature has a definite effect on your perception of it and of distance. Generally, distance on an uphill slope is viewed through a larger angle. You have more information, and your judgments will be more accurate, than in the opposite case, which is downhill. Though larger angles tend to dictate greater distances, objects may appear to be closer than they really are. In a downhill environment your sighting angle is diminished, reducing information and judgment accuracy. Be extra thoughtful. Objects may seem more distant than they really are. In undulating or broken-up conditions, distances may seem foreshortened. If the general trend of undulation, or of ground interruption, is upward or downward, subjective perceptions will be weighted as in regular uphill or downhill cases.

That's medium to long-range distance estimation. Practice a lot, maybe for years. I know. In a few years you're going to be a rich, famous, and retired DP. Yeah right, but until then, see every day as a time of practicing your craft.

VISUAL SIGHT MEMORY (ESTIMATING MEDIUM DISTANCES)

Q: When are two intervals of equal measurement a different size?

A: In space.

Estimating 10 feet to 50 feet is considerably easier than is estimating 50 to 300 feet. There are no handy right triangles to use. Ten feet to 50 feet is easier due to the larger angles involved. The angles are larger because 10 feet to 50 feet is closer. Increased angle size means increased information. The trade-off is that focus is more critical at decreased object distances. Distances at the end of the spectrum of this range are easiest to judge (10 feet and 50 feet). Twenty, 30 and 40 feet are harder because they are closer in size. This means they look more alike, which is key here.

Learn what the distances look like. I call this visual sight memory. A word of caution here. You could say 50 feet looks a lot like 300 feet. Fifty feet is 94 percent of the apparent size of 300 feet at 83° 48′ compared to 89°.

Go back out to the football field. Take a tape measure. You can put markers down if you like. They'll certainly help, but you can do without, and later you'll want to remove them to really check your accuracy.

Learn each 10-foot increment as a size. Again, as perspective operates on distance, the angle subtended by each 10-foot increment diminishes. The rate of change decelerates steadily as object distance increases from 0 feet to 50 feet. See Figure 2-5. Here is a bar graph of 0 feet to 50 feet. Here are some comparisons as examples. The first 10 feet take up 73 percent of the whole 50-foot pie. The second 10 feet take up only about 16 percent, making it about one-fifth the size of the first 10 feet. The third 10-foot interval takes up only 6 percent; a little over one-third the size of the 10 feet before it. The fourth 10-foot interval fills only 3 percent of the whole. It is one-half the size of the 10 feet before it. The fifth ten-foot interval is only 2 percent of the whole, and because it is two-thirds the size of the fourth interval, the closeness in size and henceforth shape makes 40 and 50 feet hard to tell apart.

One approach is to learn the size of 0 to 10 feet, repeating until you have it. Then do 50 feet, because it is relatively most different in size. Then go back to the other end and learn 20 feet, still significantly different than 10 feet. Then learn 30 feet, which is still significantly larger than 20 feet. Then, to learn 40 feet, go back to 50 feet. Make sure you've learned 50 feet well, because you can learn 40 feet as just a tiny bit smaller than 50 feet.

An interesting bit of estimating is possible here, once you've learned 50 feet. Point to it with your index finger with the flat palm of your hand open toward the ground. Your thumb is pointing at approximately 25 feet. Cute, huh?

MAN-MADE DISTANCE CONVENTIONS

There are certain conventional relationships that exist in the man-made world as well as in the natural world. You can take advantage of these if you become a student of the general world as well as your immediate environment.

Features of our modern environment are often quite regular because they have been carved out of nature by man, a great lover of symmetry. Thus there are many regularly occurring patterns out in the world away from a stage. This is called a location. Here, dimensions and perspectives have not been "cheated" by a bunch of set designers.

Features of our urban environment have been standardized by engineers. Most modern highways with two lanes of traffic flowing in either direction are 40 feet wide. You can legally escape from radar tickets if they vary from this dimension. A single lane of traffic is 10 feet wide. Yellow lines or white lines in any one place are of a constant length, depending on which branch of local government painted them. They are also a set distance apart. Measure a line or a space in the area you are shooting. You'll find they're much bigger than you ever thought they were. This is a great aid in shooting car stuff. They provide a constantly running tape measure. Those little bumps in the road are placed a set distance apart. Intersections are a set size, depending on their location and use. Street lights and light poles are placed at regular intervals. You can measure parking spaces, blocks of concrete on sidewalks, fence posts, even stair steps. One story of a building is 10 to 12 feet.

Inside, the story is the same. A large dining-room table or boardroom table is surrounded by chairs set apart at a regular distance. Most of the man-made world around you is very regular. Look for the regularities and take advantage of them.

A regularity in nature is found in the same ways humans repeat certain actions. Any operator will tell you there are a thousand ways to get up out of a chair. But usually, within a scene, the same actor will perform the same action pretty much the same way. Watch rehearsals. See what they do. See if they repeat, or are they trying out different bits. If they're sitting at a table, do they put their hands down on the edge of the table? If so they're probably putting weight on the table.

When they get up, they are apt to be lifting the upper body and moving farther forward than if they get up without the push up. If they don't push up with their hands, their face will remain closer to the initial plane of focus. Try this yourself. In the push up example, their face will rest for a moment a good foot closer than the edge of the table. Find this spot before you go for a "take." This kind of behavior study can be applied to many bits of business. Sometimes you can even ask an actor how he or she plans to perform a certain action.

The length of a man's gait is a fairly regular feature. Watch an actor walk a few steps in his scene and count them. After he's done, go measure the distance between the start and end points and divide it by the number of steps you counted. This will give you an average rate of pull if a scene involves a lot of walking. Remember, faster movements over larger distances tend to create larger strides. So the same man's stride will change in different situations. An interesting side to this is that if you are familiar with a certain actor's stride on a certain set, you can watch him or her walk through a set and get an idea of some of its dimensions.

Estimating focus can range from the sublime to the ridiculous. You can apply scientific rigors and you can study little idiosyncrasies. It is technical, but it can be practiced to an art form. Different situations call for different techniques. By now you have a formidable array of them.

MEASURING FOCUS

Another way of getting focus is to measure it with a tape measure. Each method of getting focus serves as a check for the other methods. Measuring does this. It can be used alone or in combination with estimating and eye focus (ground glass focus). Conventional tapes are soft, so as not to injure others as the tape is stretched across a set. They are usually 50 feet in length. You do see metal tapes, however, of only a few feet. They are used by assistants right from the film plane. This is a good check on close-ups, but watch those eyes when you're shooting humans.

General dimensions such as a set's dimensions can be gotten before a thing is known about the shot. More exacting measurements can be taken once a blocking run-through has been done. The obvious points to measure are landmarks on the set and specific points of an actor's movements and pauses. If you're short on time, even to the point of not getting general measurements, go for the closest marks. These demand the most critical focus. Also measure any "big" or important part of the shot.

A bit of set manners when taping is important. When using a tape

measure extend it over the object distance. Draw it taut to the point to be measured. Then drop it immediately to the floor. You crimped the tape at the distance mark with your thumb. You can check it as you walk back to the camera.

GROUND GLASS FOCUS (EYE FOCUS)

The most common way of getting focus is eye focus. This is ground glass focus. It is the best focus because it is film focus and it is of course the most reliable. Sometimes getting the chance for an eye focus can seem like a luxury. Hence the value of the previous two methods: estimating and measuring. But eye focus assures the greatest chance of attaining maximum sharpness. Eye focus is ground glass focus, is focus on the film plane, which is where focus belongs. This assumes the specifications of the camera, including the ground glass are at 100 percent. This is generally a good assumption, but not always true.

If you experience a discrepancy between eye focus and the lens focus etchings on the lens, set from a tape measure, make a few checks. Check to see that the ground glass is properly seated. It should be "click-locked" firmly into place. Reset the diopter. Throw the lens out of focus and refocus the crosshairs. Now eye focus the lens again. If you still experience a discrepancy between your eye and the lens, go with the eye focus only! The lens etchings are not reliable in this case. Knowing the ground glass is fixed in its proper position allows you to know its focus coincides with that of the film plane. This is because their back-focus distances coincide, as well. This is the theory of ground glass focus. Do not let anyone tell you otherwise. It is the way a reflex viewing system was designed to operate. Like the first two methods of getting focus—estimating and measuring—eye focus has pitfalls too. So they all serve as checks for each other. The order in which you'll most often be able to get focus in any setup will likely be estimating, measuring, then eye focus.

Interactional Factors

Here are some of the factors affecting eye focus ability. The first is diffusion/contrast. Diffusion on the lens, such as filters, nets, diffuse lighting, and atmosphere, including smokes and fogs, all serve to soften edges. This interacts with a neurological process in our brain's focusing system called surround inhibition. It has to do with edge contrast. Edges are what we focus. As we perceive an edge, we perceive light stimuli of significantly different intensities. The brain enhances this

contrast by shutting off, or inhibiting, neurons that read dark next to light and vice versa. This increases edge sharpness, which is the criterion we use to focus. Diffusion decreases edge contrast, which causes less stimulation of this process. This reduces further our sense of edge contrast. This reduces our ability to focus.

Certain colors seem to make objects more difficult to focus. Sharp eyes in a person being focused mean sharp focus to the person focusing. Gray eyes seem particularly difficult to focus. So do skin tones. This is anecdotal and is from experience only. There is no scientific documentation to support this. It seems likely the effect has to do with medium tonality, as opposed to values closer to either end of a contrast gradient.

Texture has an effect. Smooth surfaces lack edges, hence they lack well-defined shadows, hence they lack clearly defined edges.

Fatigue is an obvious factor. However, there are two types. The first is physical. The second, though often not considered, can have a more immediate and profound effect. This is neural fatigue. Receptors in the eye receiving stimuli can become overstimulated. This is a result of intensity or duration. This results in fatigue and a momentary loss of ability to focus and judge focus. This is called habituation. Avoid overly bright single-point lights or highlights for focusing. Don't look at focus too long. Look away, then look back. Don't overfocus. This is important in setting diopter focus, as well.

Age is a factor. You'll notice that an older person's diopter focus will often change throughout the shooting day. If an operator begins to complain of softness, check it, but consider asking him if he's checked his diopter setting lately.

Stress level affects the ability to focus and to judge focus. This is probably a process related to habituation, sensation overload. Importantly, stress is also why an operator may say something was soft if it happens particularly fast. This is especially true if the shot was difficult for him. This is not a way for him to cover his mistake, unless he's a creep. Also, he has a lot of composition and operating to look at and think about, on top of just seeing focus. So don't get shaken.

Eye cup pressure can change the shape of your cornea. Don't smash your eye up to the eyepiece. Think first and use a light touch.

Temperature affects focus in a lens for the focus puller. You may re-mark a lens that experiences a slight shift when using a telextender. After taking it out of the prep room and into a much higher or lower temperature, you may experience another shift in either direction. Some lens techs maintain that higher temperatures cause a lens to shift longer, in terms of its etchings (higher footage readings), and vice versa. Be aware of this. Minor collar shifts can make a significant difference on a long lens.

The second effect of temperature is simpler, but can be harder to correct. Condensation can form on the eyepiece. In cold conditions it is cleared by raising the temperature of the eyepiece or by a quick blast of air. If condensation forms in a lens, the only cure is to sit on your thumbs until it goes away.

Both spinning-mirror and pellicled cameras have drawbacks. Mirror flicker is fatiguing at certain speeds, and it is hard to see fine focus through it. A glass pellicle, though flicker-free, transmits less light and can be hard to look through, especially at a low-light scene.

Lens parameters can greatly affect ability to see focus. The maximum telephoto end of a zoom lens, at maximum aperture, shows focus most easily. This is because it so readily shows what is out of focus. The wider the zoom setting, and the smaller the aperture, the harder it is to set focus. A wide-angle lens even at large apertures has a very broad shouldered depth-of-field gradient. Setting a wide-angle lens to focus by tape alone is tough, because the etchings go from, say, 12 feet to infinity. So where in the black space is 17 feet, 6 inches? Eye focusing produces no abrupt snap in or out. So use a combination of eye focus and tape to kind of reach an agreement. If the lens is only moderately wide, like a 35mm (in 35mm format), it can really get you. It's wide enough to be hard to snap focus, yet long enough to have a considerably limited depth of field at short object distances. On the same count, only the sharpest operators catch softness "in shot" in spinning-mirror cameras using wide-angle lenses. To the same end, always check that the diopter is properly set.

Finally, when eye focusing, allow for the above limitations of the eye/camera system. Choose moderately contrasty objects, like slates, lettering, eyes, grids, and charts. At night, rather than focus directly on a light point, it's better to shine a light on a contrasty object. Bright light from very bright objects, mixed with other factors, can result in an "in-eye" form of halation from glare. Very bright light strains the eye (physiologically and neurologically). High contrast causes strain, as well. Both can cause habituation and neural fatigue. Glare optically reduces contrast, and strain reduces the eye/brain's ability to discern contrast and sharp edge focus.

Methods of Achieving Focus

Eye focus is usually done in a few different ways depending on who all is involved. This can be the first assistant only, the first and the operator, or the first, the second, and the operator.

In all cases you should have the say on what marks are to be taken.

You can't insist for obvious reasons. Still, most good operators understand why it's optimal to defer to your expertise.

In the first case, with only yourself, the process is obvious. With a first and an operator, he will eye focus and you'll mark the lens. Always ask for the most important marks first. The two of you may get cut short by an anxious director or production manager. Also ask for fewer marks than you may take by yourself. Why? Because the man is busy.

If you are in front of the camera with a slate (for focus) and the operator is focusing and marking the lens, take fewer marks. Fewer marks reduce the possibility of confusion as to what all those marks mean, once you get back to the camera.

If you have a second assistant with you, his time should be yours, and you can take a few more marks. Please, don't plant the poor guy in the middle of where others are trying to work. Again, get your most important marks first, because both of you may get "shooed" off the camera at any time. Even with a second you may consider going out yourself with the slate. Let him focus and mark the lens. You know what marks you want, and you won't have to be shouting and waving across the set.

If the operator is helping you and the second, keep the communication simple. The operator will usually defer to just you talking to the second even though he's focusing. Avoid confusion. Ask for fewer marks. I would never send a second assistant out with a tape and slate in this case unless it is really necessary. In that case the operator shouldn't mind the inconvenience of such a circus.

FOCUS AIDS

Besides traditional methods, newer methods have been made available by modern technology. There are devices, electronic and optical, to aid measurement. Computer-assisted focusing systems are available. They even come with their own crew.

Optical yardsticks that give out a reading of distance sighted seem like a good idea. Their optics are dark and hard to focus and look through. Maximum distance measured is only 40 feet.

Electronic systems can measure hundreds of yards. You need to have a second piece of equipment to bounce back the signal at object distance. This requires two bodies to use the system and the second body would probably be in the shot. It also takes extra time to go through these motions.

A computer-assisted system, complete with crew, is available. It is

for one-time shots. It can pull from full figure at 300 feet to full-frame eyeballs and never go soft. It is obviously expensive, but it has a value for special applications.

This book is trying to stress an approach that is as organic as possible from setup to shot execution. All these specialized devices and systems stray from that clean, core approach.

MAKING MARKS

Focus marks are a collection of different methods of notating "in-shot" focus points and labeling them for focus pulling during the shot. Some methods are obvious. A few variations on some of the standard methods may, however, speed the setup process (making marks), as well as limit confusion in complicated shots. This is done by simplifying. This will make recall and focusing easier during the shot.

Marks come in different sizes, shapes, and even material. They are made in a few different ways. All have advantages and disadvantages. Marks are made on lenses, follow-focus disks, and floors. On cameras, they are focus marks. On floors and sets, they are dolly marks or actor's marks. There is usually a trade-off between speed and simplicity for clarity and precision.

There's a certain old guard charm in a few lines made on a lens with a grease pencil that is then stuck back behind the ear. It's fast and simple. Some very good focus pullers can do this in a very complex shot, even with numerous marks. The posturing seems kind of like an old-timer thing. It's also Zen. But for many, grease marks can be hard to read, confusing to recall, and not precise enough. And if you have to make too many marks, grease pencil can be messy. Grease pencil will work in wet weather.

Tape strips can be more precise and easier to read. They take a bit longer. They're cleaner. The tape can cover lens etchings, which disallows compensating for missed actor's marks or other deviations. To help, you can make the strips thinner, but they are harder to write on and many marks become harder to read. They "erase" quickly with one quick zip of the tape. Tape does not stick in wet weather. If you make a mistake on a strip, you often have to start all over. When marking tape with pens, I've found medium points okay for most uses. But the longer the lens, or the faster moving the object, the finer a point you must use. This is so you can make more marks closer together that are more precise.

Tape arrows offer you the changeability of grease pencil. They "erase" quickly. They can cover lens etchings. Thin arrows avoid this,

but it's harder to write numbers on them or read them. They're harder to handle and place on a lens with accuracy if your fingers are at all big or cold. In wet weather tape arrows will not stick to the lens.

All methods have times they should be used and times they should be avoided. No one method should be used to the exclusion of the others.

Differentiation by set and series is key in mark making. A mark of any kind distinguishes particular focus points in the set, such as actor's marks or dolly marks on the floor, as well as focus points on the lens. These are distinguished from an infinite number of other points that may be selected. They tell you to twist the lens to, or focus, these points. But two marks can coincide, or a set of marks may overlap. This occurs when objects approach and recede in the same move. This also occurs in multi-tiered crane moves or circular dolly moves. Such marks, though occurring at the same points on the lens collar, must have a way to be differentiated from each other.

Marks should refer only to camera position and/or object location/position. A mark must not specify an object. This is because any object or person can step into or come into a certain focus position in front of the lens. Do not use different-colored marks for different actors, like a second assistant uses different-colored floor marks. This can create instant confusion.

Marks are made unique from one another as sets or sequences. A series or set of marks may be a different color from other sets. A sequence of marks is composed of marks that all have numbers that are different from all the other marks in the sequence.

Crane moves, especially free-form moves (hose down the rock band with the camera), are probably the most complex. Here marks can be put into sets by color and the sets of marks numbered into sequences. But before we start with the most simple case, know this simple, but useful guideline.

When choosing and making marks, take a tip from cognitive learning psychology. Seven elements, plus or minus two, is the optimal number of objects for storage and recall in human memory processing. Object distances that increase and decrease, or vice versa, in the same move is the simplest case. The object to be focused may be moving, or the camera may be moving. Both may be in motion. Simply use one color of pencil, strip mark, or tape arrow for objects that approach and a different color mark for objects that recede. You can number these marks if appropriate. With tape strips, numbering can be cramped, messy, hard to read, and confusing. With tape arrows it's easy.

With tape arrows you can avoid colors and just put two numbers on the same arrow. If you need three numbers, it can get cramped, hard

to read, and confusing. And if there are any changes, which are bound to occur, things turn into an illegible mess.

A multi-tiered crane move is very complex, but it can be simplified. This is done by breaking down the move into three simpler moves. Let's say you have an arcing move. Each end of the arc is farthest from the object. The midpoint is the closest. Now the director and producer, each for his own reason, call for three levels, or tiers, of "bucket" swing. Even if you stick to the magic seven rule, you already have twenty-one marks.

Forget it. And you will. The answer: make each tier a set that is distinguished by a single color of arrow. Then number each color set in sequence, one through seven. Here you'll have to put two numbers on some arrows. Use big arrows. They're easy to read and write on. Again, seven is the optimum maximal number. If you can get by with fewer marks, you're better off. The fewer marks, the less confusion and potential for disaster. If you make a mistake in setting and labeling the marks, it will be easier and quicker to correct. Always use as few marks as possible. I've met one assistant who claims he never uses any marks. Well, if you never use any marks, you never have to change them.

Marks can and often do change. Especially if a director/cameraman is blocking out a shot. A method of numbering marks must take this into account. It must allow for change without necessitating a lot of renumbering. It's messy, confusing, and takes time.

This numbering method works for floor marks (dolly marks) and lens marks. If, while blocking, they give you the marks in order—first, second, third, etc.—life is fine. This is rarely the case. Dollies are usually parked first, and the camera is aimed at the "meat" of the shot. The rest of the shot is built around this. The "big" part of the shot is rarely the first part, especially in dolly moves. Often the middle or last part of the shot is set up first, and its marks are taken first. But what is the number of these marks? How many marks will go before? If you're doing an involved, heavily choreographed move, there could be some very important points you'll want to mark between the first mark and the last. But you haven't been shown those yet, and you don't know whether between the first mark and the last mark there is one additional mark or a hundred. So when you give yourself a mark on the lens and on the floor for this last mark, what number do you give it?

You can't know, so the answer is to label this last mark with an "X." An "X" can be any number, and at this point it is any number. Because of this, any number of marks can go before it. This happens when the director, or whoever, goes back to the "top" of the shot, which is most common after he sets the "big" part of the shot. The director will usually, at this point, set a first mark. Give it a #1. You now have a #1, a lot

of feet of track, and an "X." If nothing important or critical for focus is going on in between, you could change the "X" to a #2 and be done with it. But wait! "I've just had a brainstorm!" the director shouts. He leaps back onto the dolly as he knocks you over. "In between, let's do this, this, and this!" He sighs, marveling at his own awesome genius, calls for his "cell" phone, and wanders off muttering to himself. He's just given you three more marks. These are as rock solid as a mountain of Jell-O, which is what Hollywood is built on. You now have marks numbered 1, 3, 4, 5, 2. If you had left the "X," you'd have marks numbered 1, 2, 3, 4, X. Which looks easier? Also, you may want to add a few marks of your own between #4 and "X," if you're in shallow depth of field.

But other things can change, like the client. The director is now talking on his phone. Suddenly the AD is there. The client has added a shot. "We can't go over schedule or we're dead," the producer whines as his dream of a Mercedes turns into a Lexus. The director will save the day. He'll make this shot into a larger shot that will cover two shots on the board, and we'll still have time for the client's shot. The director leaps back onto the dolly. "Take me to one!" He masterfully commands and heroically begins expanding the shot.

The last mark is no longer the last mark. The move is extended and four more marks are given. What do you number these? I suggest any of these three approaches. Choose the one that you like best. You can now have 1, 2, 3, 4, X, 6, 7, 8, 9, etc. I like this best. It's the least tricky. Skip a number and continue on, then later you can change the "X" to a #5, or whatever number is appropriate. Or at the time, you can immediately replace "X" with its number and continue on. You now have 1, 2, 3, 4, 5, 6, 7, 8, 9. Finally, you can leave the "X" in its original position and label subsequent marks X1, X2, X3, etc. I like this least. It's tricky and confusing to read. It does show what extra (X-tra) marks were added, but it's rarely necessary to remember what additional marks were given later.

Remember! Whenever possible, keep it simple. After more marks have been added, go back through the move and see if you can remove some of the less critical focus marks from the lens.

But life, especially on a set, is not a simple thing. Everything is subject to change. Even the first mark. How do you number a mark that is no longer the first mark and still keep it in sequence? What numbers are less than one? What number is even less than zero?

Use the numerical meaning of "one" to change the designation of the "first" mark. This means that the number "1" is merely a unit of an infinite series extending negatively and positively along a continuum toward infinity. One meaning "first" is merely a convention that does

not serve our purposes here. It may as well be #47 or –305. So if a director changes the first mark, you may leave the number "1" mark in its place. Obviously, number the new mark zero, since that precedes "1" in our system. And next use "00." But what if "they" keep adding first marks? Use minus numbers. But notate them a little differently than you normally would. Minus "1" (–1) looks too much like "1" and so on. Replace the minus sign (–) with a zero (0). This is easily distinguished visually. So you might have (going in reverse), 01, 02, 03, 04, etc.

But wait! What if the director goes way down the track, past the head end of the shot? What number do you use? Remember, this mark represents the last mark going in the negative direction. Because we can't know for sure its ordinal notation, we use an "X" and because it's in the negative direction, we use a "0." So the number will be 0X, of course. So you can have 0X, 03, 02, 01, 00, 0, 1, 2, 3, etc. And again, any number of points can be placed between 0X and 03, because 0X can be any number. So there is your bullet-proof, director-proof numbering system.

An orderly, cut-and-dried system of mark taking and labeling really pays off in situations that seem less cut-and-dried. A system, any system, introduces order and simplicity when seemingly fewer rules than normal can be applied. Here are a handful of special cases. They often pose complex focus problems but are regularly seen for certain applications (shots).

SPECIAL CASES

Multiple Mark Designation for Circular Dolly Track

Lovers, performers, and group interviews. Ask an assistant what he fears most. More than long lenses, more than low light, comes the answer: circular dolly track. It's a favorite for those lyrical camera moves on lions, tigers, and bears, oh my!

The simplest case is one object in the center of a circle—as long as it stays there. Actually, I'm going to treat this last. It is simple enough that there is a fairly rigorous way to cover the focus for this setup. You'll appreciate it after going through a handful of related paradigms.

Three objects are much like two objects, so we'll do three in one arc. This is commonly used in multiple artist (guest) interviews. They're usually seated. This is good. It restricts movement. It doesn't control for leaning. Caution is still needed on long lenses and close-ups are a staple of this form of shooting. See Figure 2-10.

Marks will be colored and numbered. Here, because each object is

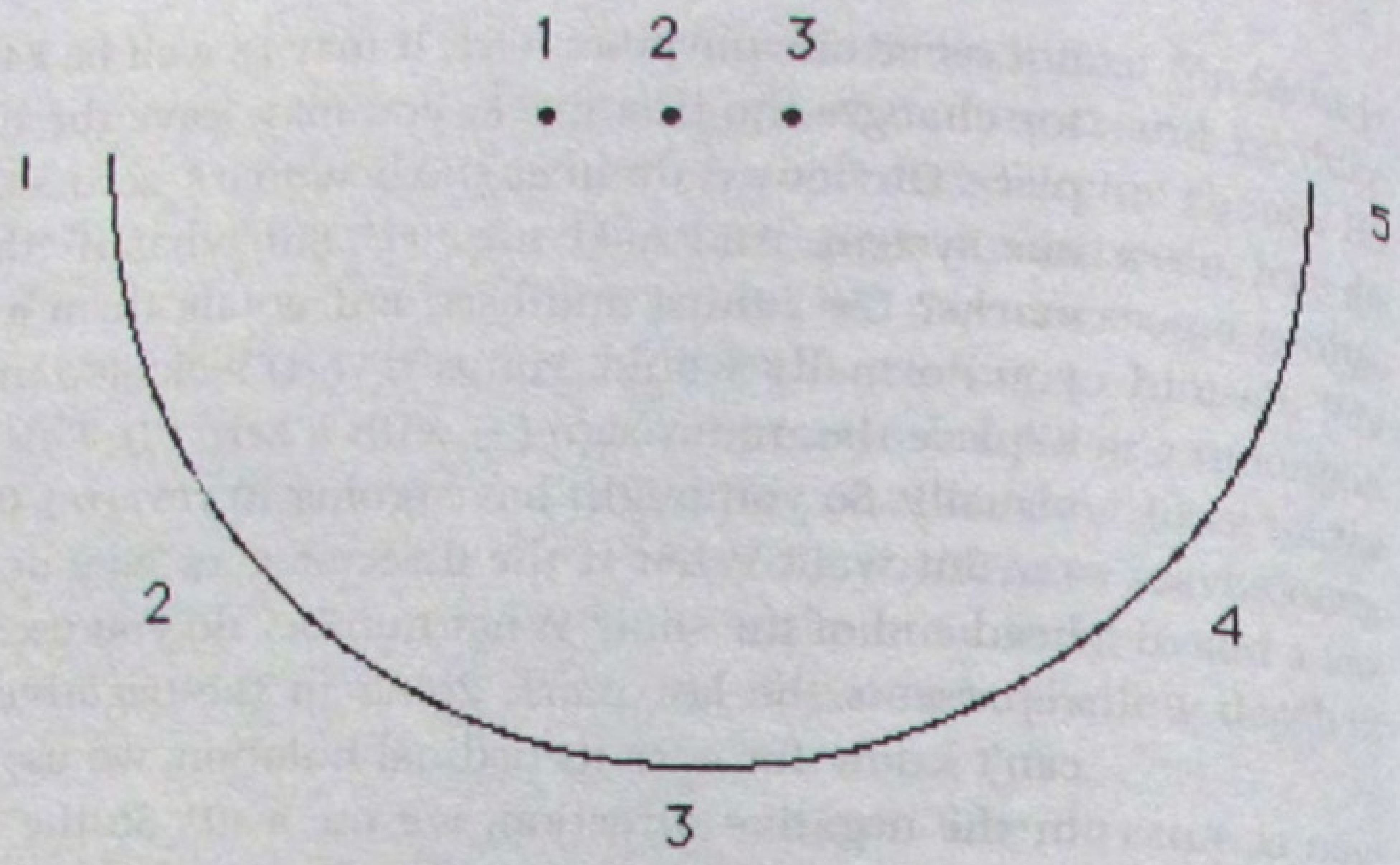


Figure 2-10. Circular track and multiple marks—one arc, three objects in center. Take extra marks front and back as needed on CUs (close-ups), remember the DOF zones, use colored tape for each object and number mark, and make extra front and back marks for leaning.

"nailed down," you may use a separate color for each object. Red can be for one, yellow for two, and white for three. In this example, two is in the center. All points on a circle are equidistant from its center, so in theory one mark should provide focus for all camera positions. Marks for objects one and three, though different colors, represent symmetrical object distances and in this sense denote the same "focus." They should fall on the same place on the lens or follow-focus disk. In the interest of clarity you might place one object's (color) marks on the follow-focus disk and the other object's (color) marks on the lens. Object one and object three's numbers will mirror-image each other, crossing over at position three. In the interest of being "fast," you should be able to get all marks by taking object two's central mark and then those of either object one or three, not both. So you need to get only six marks instead of eleven marks. This should cut your time in half. Cover leaning by "squeezing" the lens. Video assist is an obvious help in knowing whose "single" you're on. The DP/operator will probably be free-forming. Remember depth-of-field zones, but obviously you should try to stay as "right on" as possible.

Next is one object-one arc. This object is not in the center. See Figure 2-11. This means fewer objects, but more marks per object. Though off-center, there is still symmetry. Unlike one central object, anywhere on the arc is not the same focus, but symmetry helps because #1 and #5 are the same focus. This is true for #2 and #4, as well. Take three marks instead of five. Take extra marks, as needed, along the movement axis (leaning). If the object moves along axis A, camera position #2 needs extra marks. If the object moves along axis B, camera position #4 needs extra marks. Camera position #3 might need extra marks if movement

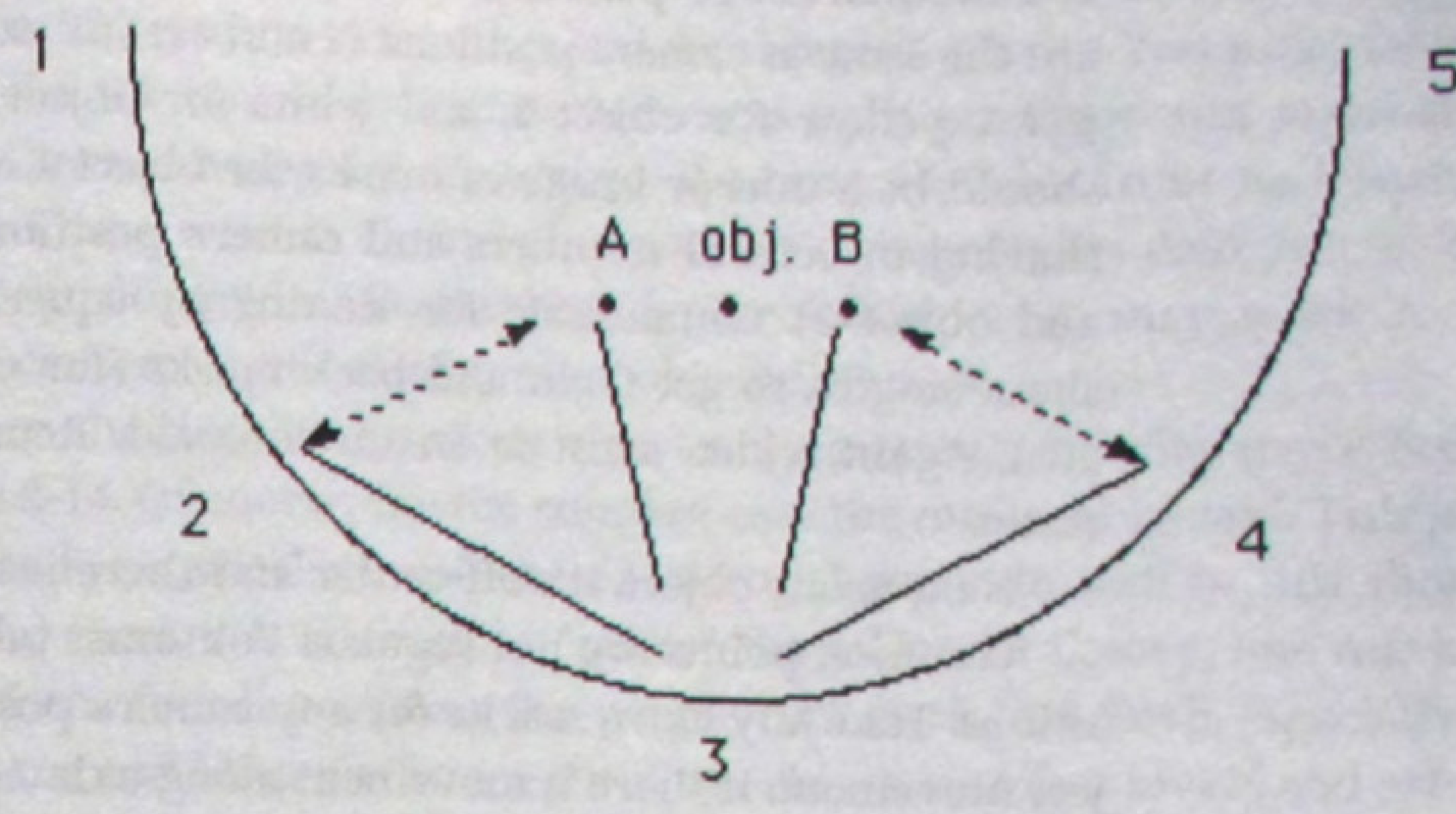


Figure 2-11. One arc, one object not in center. Take extra marks for any camera position on axis with object movement. If move (A), position #2 needs extra marks, #3 may also. If move (B), position #2 needs extra marks, #3 may also. Positions #1 and #5 will probably not be used. Use colored tape and # marks, but label marks A and B for front and back.

along axis A or B is extreme. Camera positions #1 and #5 will most likely not be used, as this would require almost a 360-degree set, which would prove lengthy and more difficult to prop and light. If this is done though, take marks for #1 and #5 and take extra marks as needed. Remember depth-of-field zones. They may save you here with greater object distances at #1 and #5. Use one color tape mark, but designate front and back wherever extra marks are taken (for example, 1F, 1B, 2F, 2B, etc.). This should cover leaning.

Next is a case of three objects that are off-center. See Figure 2-12. Anywhere on the arc is not the same focus, but symmetry helps. This is because of shared focus positions of marks. You can cover all focus marks with eight marks instead of fifteen. Use a different-color mark for each object and number them accordingly. Start with center object

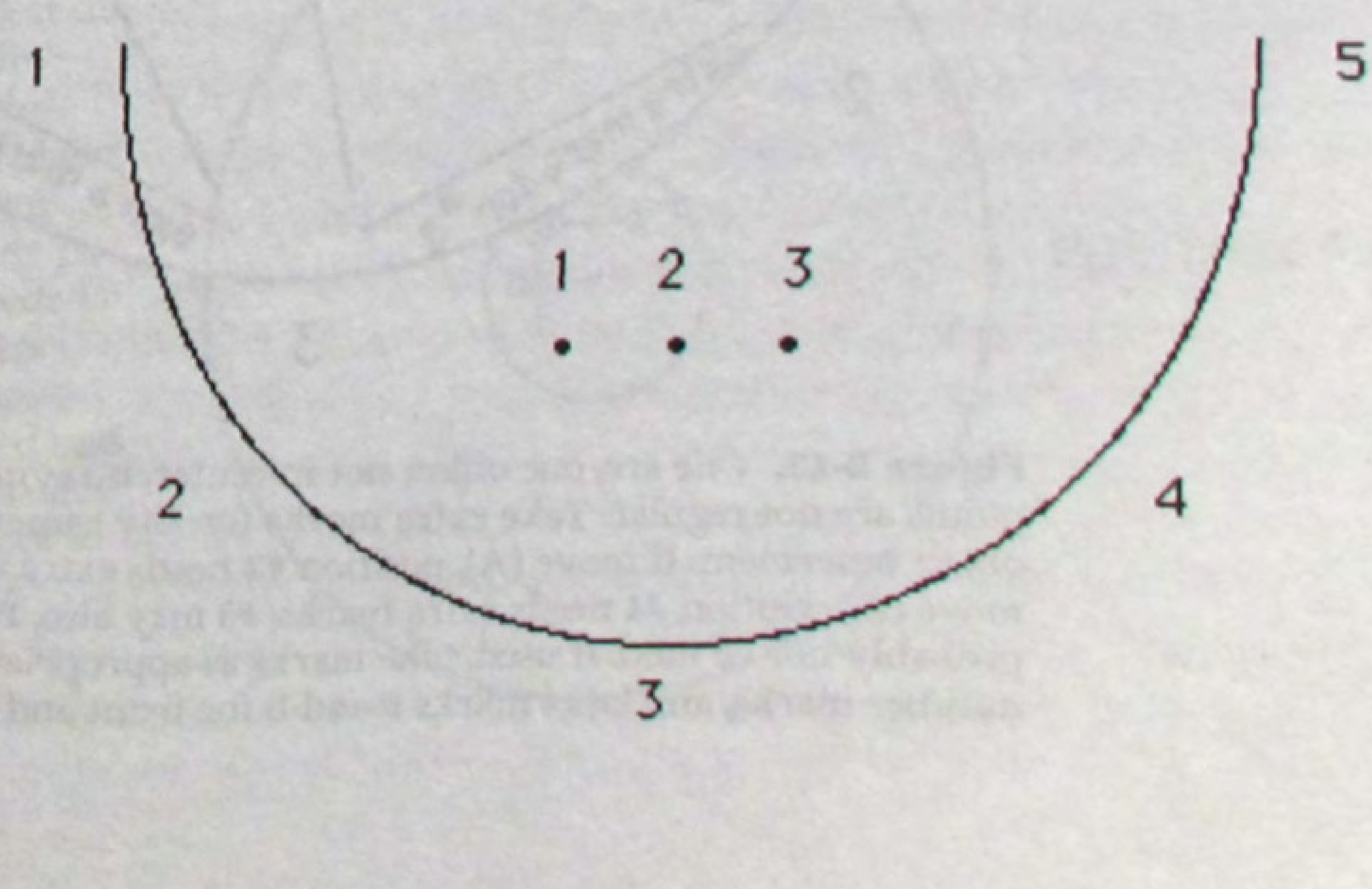


Figure 2-12. One arc, #objects not in center. Multiple guests are usually seated to restrict movement. Extra marks A and B needed on CUs. Remember DOF zones and use colored tape for each extra front and back mark for leaning objects.

2. Take marks for positions #1, #2, and #3. Camera positions #4 and #5 are the same as camera positions #1 and #2. For example, use red for object 1, yellow for object 2, and white for object 3. Marks for object 3 should be a mirror image of marks for object 1, with crossing over, or sharing of central numbers and camera position (camera position #3 and object 2). Compensate for leaning by squeezing. You'll probably shoot singles, so get front and back marks (for example, 1F, 1B, 2F, 2B, etc.). Again, video assist is an obvious aid. Remember depth-of-field zones.

Next is one object. It's off-center and there is no symmetry.

Common points are not regular. You must take marks from all positions. Take any extra marks for any camera position on axis with object movement. If there is movement along axis A, position #2 will need extra marks. Position #3 may also require extra marks, depending on the amount of movement and the depth of field. The same is true for position #4. If there is movement along axis B, position #4 will need extra marks. Position #3 may also, again depending on movement and depth of field. The same is true for position #2. Positions #1 and #5 will probably not be used. Take their marks, as needed, if they are used. Use one color tape. Number them and label them front and back accordingly (for example, 1F, 1B, 2F, 2B, etc.). See Figure 2-13.

Three objects, all off-center, is probably the most difficult of these

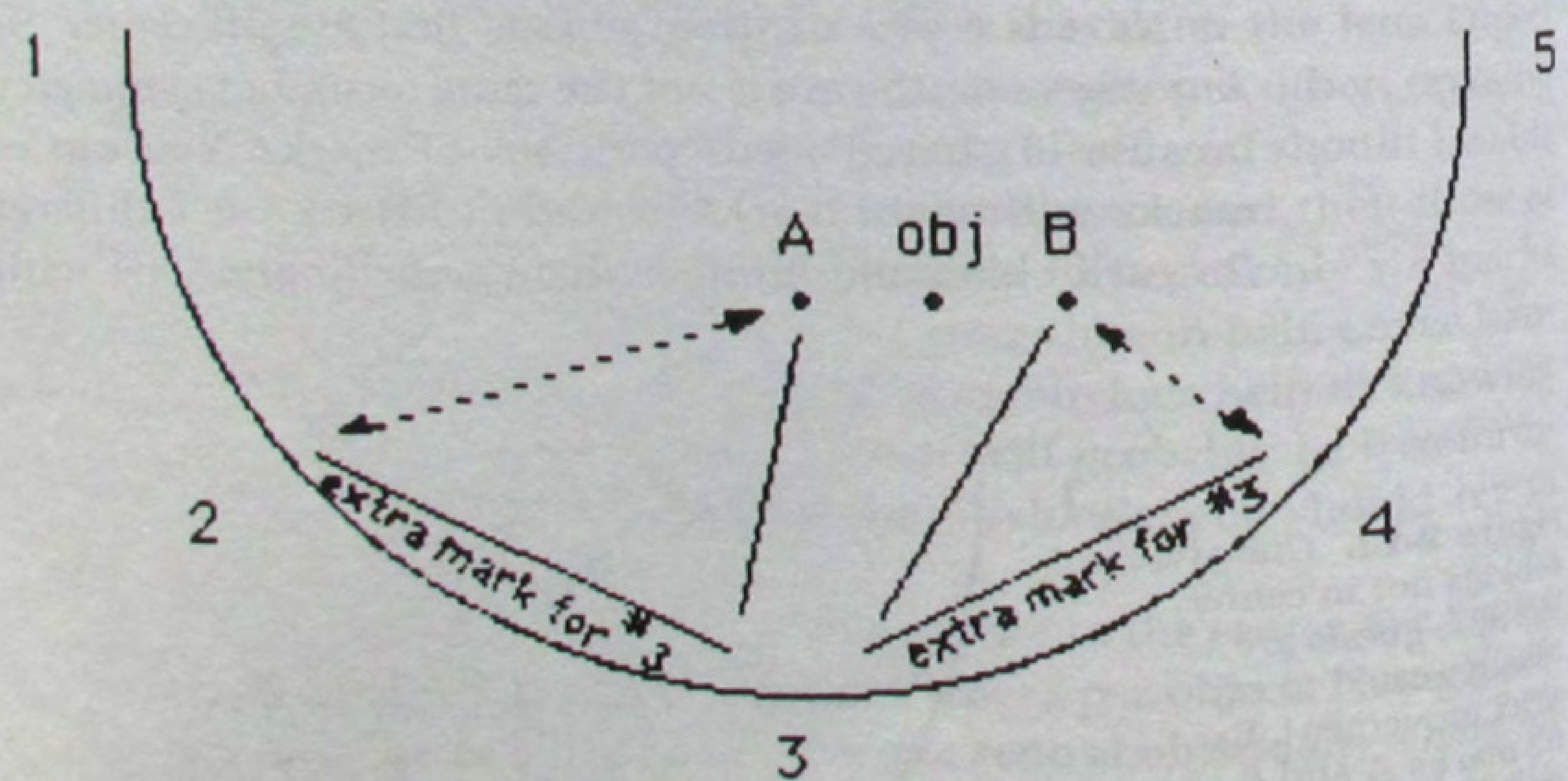


Figure 2-13. One arc, one object not in center, no symmetry, common object points are not regular. Take extra marks for any camera position on axis with object movement. If move (A), position #2 needs extra marks; #3 may also. If move (B), position #4 needs extra marks; #3 may also. Positions #1 and #5 will probably not be used. If used, take marks as appropriate. Use one color tape, number marks, and label marks F and B for front and back.

situations. The least can be done to simplify it and the least can be said about it. There is no symmetry and no common marks. You must take all marks for each object, at each camera position. Color and number them. Cover leaning by squeezing. If necessary, take front and back marks. Video assist is always a help when doing singles. And you will definitely do singles. Remember, depth-of-field zones may work for you at camera positions of greater object distances.

Now the simplest case: one object on-center in a circular move. See Figure 2-14. Of course, for the simplest case the most can be said. This is a classic for a vocalist's romantic close-up. Lovers do well in this shot too. The camera is allowed to "caress" the talent. In theory, one mark holds focus for all positions. But people rock back and forth, especially musicians and lovers, who are emoting. This means that lovers and artists don't always remain in the center and they don't necessarily remain in one mark focus.

This is free-form shooting, where they roll the camera and roll the playback and shoot. At any point, you can't know where the camera will be. Talent may move along axis A or along axis B. The camera could be perpendicular to the axis and no focus change is required. The camera could be on the movement axis, which would require a focus change. Taking one mark and squeezing can get hairy. It is also very Zen, if you can do it. But messing up isn't. Well, this can be argued, but anyway... There are some guys who can do this with one mark. And you should be ready to try this at any time it becomes necessary to "just

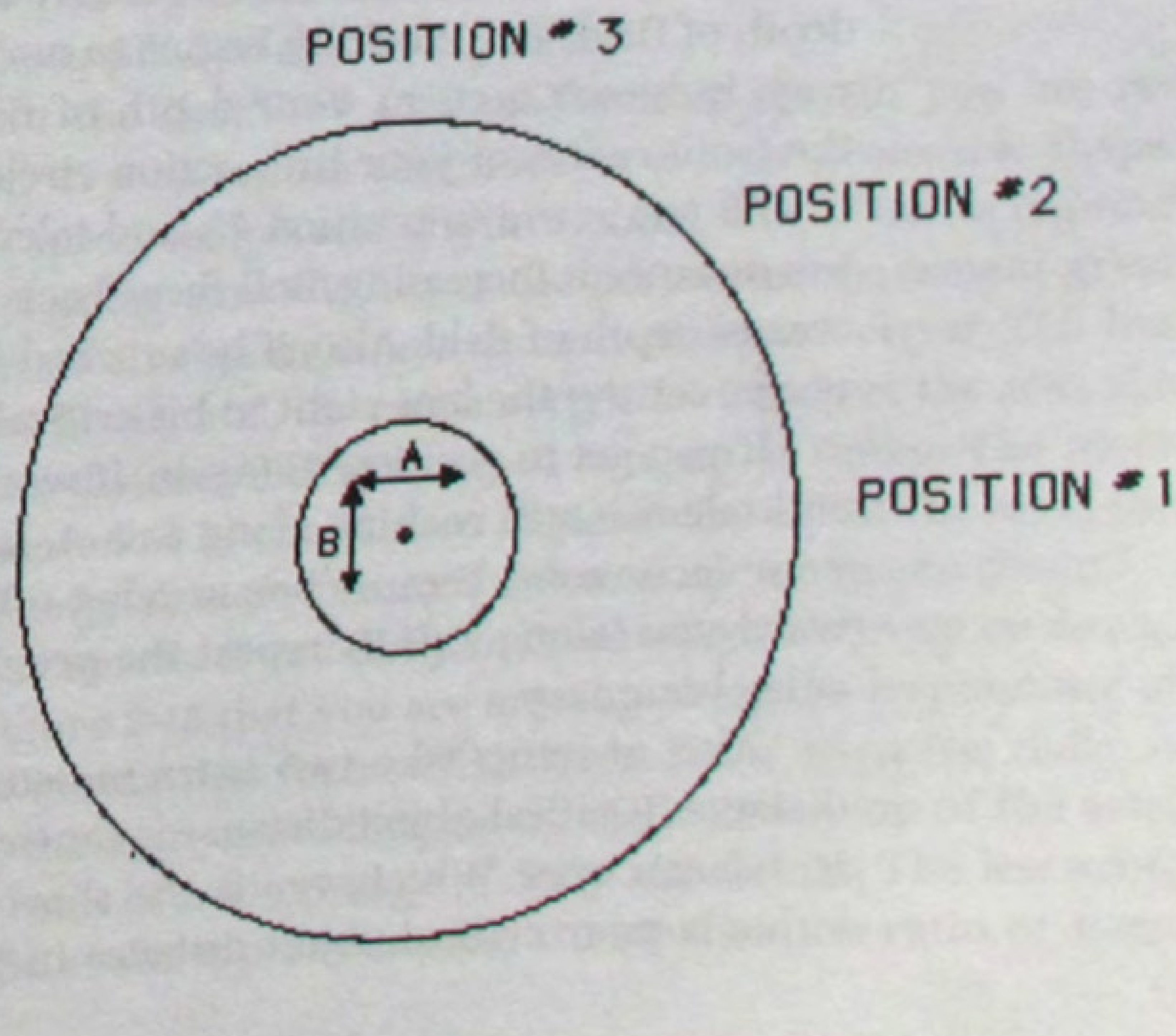


Figure 2-14. Circular track. At position #1, measure and take mark at critical object distance. Focus lens 1 inch forward. Pull focus 1/2 circle diameter as object nears object circle perimeter. Roll focus back as dolly to any other position. Repeat steps as needed at any new position when there is on-axis object movement. On axis A—forward and back. Cross-axis B—side to side (talent may turn to camera to "swap" these parameters).

go." The alternative is an infinite number of possibilities for mark taking. This would take too long, be too confusing, and guessing what mark would most likely be used would be purely that—guesswork. By the way, by not taking all possible marks, you are engaging in a heuristic process. Remember that?

Here's the best way to do it. Try to have (basically pray, because you can't ask) the object centered. Sometimes a director may sacrifice a bit of "interesting" to give you a fighting chance of getting his shot. Draw a small circle on the floor, around the object's ideal central position. Make the diameter of this circle twice the difference between the measured distance to center and the near limit of depth of field for the taking lens, at the taking stop, not the whole depth-of-field range. This will make the circle conservatively small.

Now, with talent in there, squeeze lens focus to one inch in front of measured object distance. At close focus distances, this will buy you an extra margin of safety in the smallest part of your depth of field zone. The combined effect of pulling focus forward and the ⅓/⅔ depth-of-field rule breaking down at close values (½/½) will leave the front part of the zone almost the exact same size as before and an inch closer to the camera. The back range falls off to a slightly greater degree, but this too is small and we aren't using the back part of the zone much, in this case anyway.

If the actor steps toward you and crosses the circle with the plane of his face, squeeze back half the diameter (radius distance) of the circle. At camera position #1, the actor moves along axis A. The back part of your depth of field zone still overlaps the circle talent has just crossed. Now more care is needed here. You have shortened focus and decreased depth of field, and the dolly begins to move to position #2 (or the other way, it doesn't matter). Your depth of field is still reaching back into the front radius of your little action circle that talent is standing in.

As you move to position #2, and talent is still leaning forward, object distance is increasing. Roll focus back to its original setting. This increases depth of field. Also, if he's rocked back, which he probably will, you're setting the lens right to his critical focus.

If you get to position #3 (again, it works in the other direction also) and talent is still rocking along axis A, he'll be smack in the middle of your focus zone, because he's moving off axis anyway. If he moves toward you (along axis B), repeat the previous step as he bumps the circular boundary.

Also, at setup take two extra measurements besides critical object distance. (Critical object distance is camera to center of circle, or camera to talent's eyes. Whichever is the shortest object distance or smallest value is your critical object distance in this special focus-pulling tech-

nique.) The first of the two extra measurements will be camera to near edge of the action circle. The second of the two extra measurements will be camera to the far edge of the action circle. Put small marks for them on the lens. Your depth of field will cover a circle that measures across one half the radius, up to the full action circle depending on the circle of confusion that you are using. High-tech DPs know this changes according to your projected format. As you are squeezing focus in the shot, check to see that you're staying nearly between these marks. Most likely you will be staying closer to the front limit, as opposed to the back limit. During rehearsal watch the actor to see if talent favors a particular direction off-center. Most rock forward, where focus is more critical. If talent rocks back and you squeeze back, depth of field will increase, making things easier. You must still be very careful at these "low tolerance" parameters. This somewhat scientific approach works at light levels as low as T4 on a 50mm lens. Most guys (DPs) I've done this kind of shot with will light to a T5.6 or T8. They promise you a T8, but you usually get a T5.6.

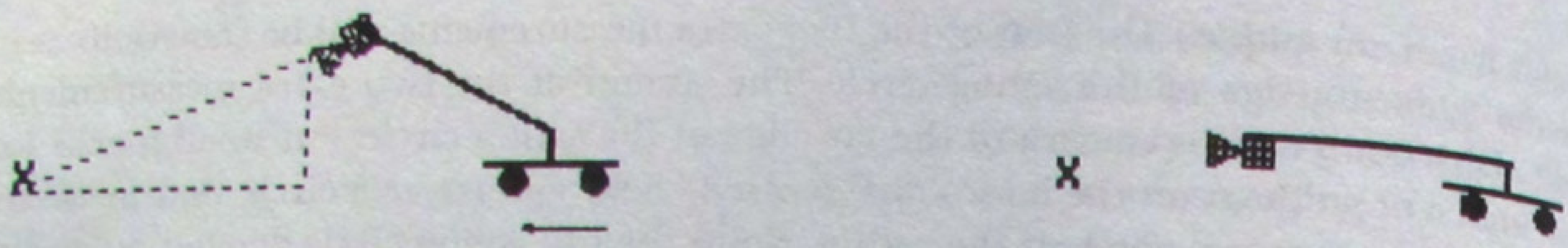
Complex Crane Moves

Besides moving in great sweeping arcs, cranes can dolly side to side or in and out. This creates the potential for very complex moves in three-dimensional space.

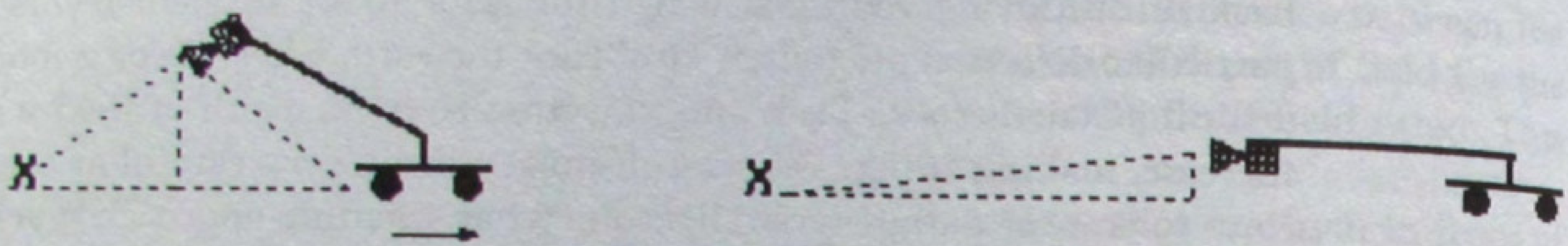
Here you must really depend on operator-assisted eye focus and marks. Take sight lines off the set to try and establish an idea of where you are in space, during the shot. Start and end focuses can be estimated if you've developed a general feel for the "trig" functions. Certain general rules can be applied to almost any shot.

Think about the shot. Try to visualize it as though you are removed from it. Try to reduce the move to a basic geometric shape. Then study the speed, tempo, and rhythm of the shot. When is it going fast? When is it going slow? When is the percent of movement great with little percent change in object distance and vice versa? The less vertical, or more horizontal, the camera angle at the top of the arm, the slower the object distance changes as you arm up or down. The more vertical the orientation of the camera angle at the top of the arm, the faster object distance changes through a "boom up" or "boom down."

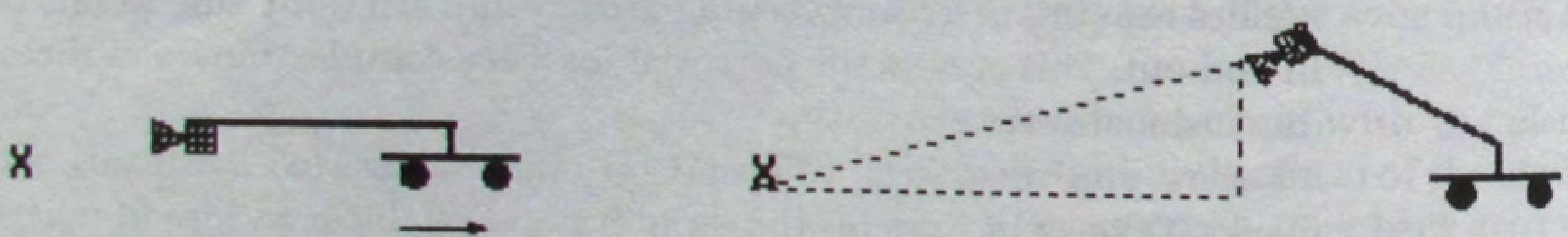
Let's combine moves. If you dolly in or out as you arm up or down, you see from Figure 2-15 that you are moving along the hypotenuse of a triangle. This means that focus will change faster than the dolly is moving. Again, the more acute the camera angle at the top of the arm, the greater the ratio of focus change to dolly movement. The less acute the camera angle at the top of the arm, the smaller the ratio of focus



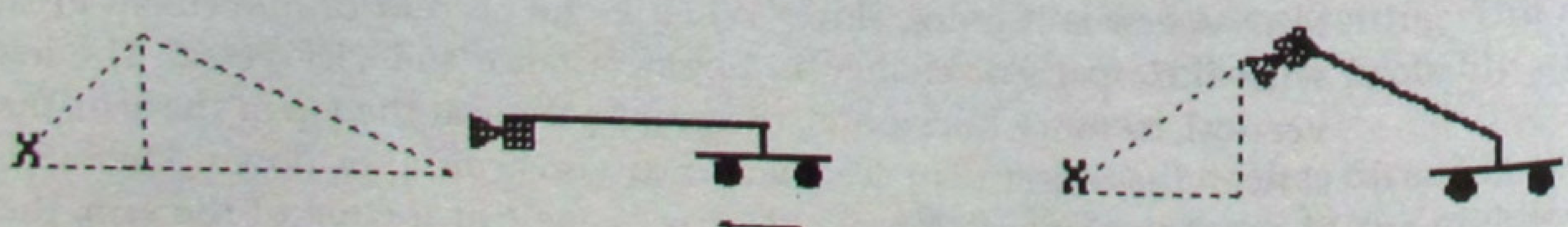
A. DOLLY IN, BOOM DOWN. CRANE MOVES DOWN HYPOTENUSE.



B. DOLLY OUT, BOOM DOWN. CRANE MOVES DOWN HYPOTENUSE OF SIMILAR TRIANGLE TO A MORE ACUTE TRIANGLE.



C. DOLLY OUT, BOOM UP. CRANE MOVES UP HYPOTENUSE.

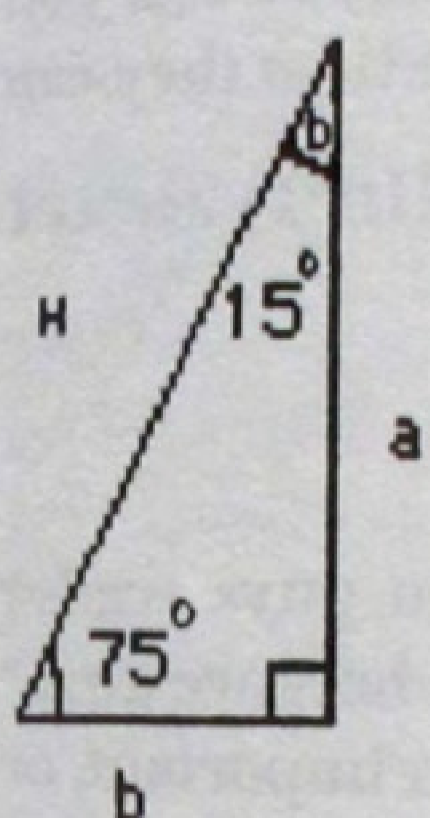


D. DOLLY IN, BOOM UP. CRANE MOVES UP HYPOTENUSE OF ACUTE TRIANGLE.

Figure 2-15. In dollying in or out, if camera (lens) axis and dolly axis share a common orientation (direction of travel), lens focus will always change faster than dolly's relationship to object focus (point). Distances on lens will change faster than distances covered by the dolly.

change to dolly movement. As lens axis to ground angle approaches zero degrees, focus and dolly will change footage-wise in a manner that approaches parity.

A general use of triangles can also show a couple of simple relationships for limited parameters at the start and end of moves on the crane arm. Looking at the triangular math tables that accompany Figure 2-16, you can see that for any elevation of the camera, at a 60-degree down angle, your object distance is twice that of the camera elevation. At a 15-degree down angle, your object distance is approximately equal to that of the camera elevation.



Elevation of 10′ = a (height)
Internal angle of ∠b (Camera down angle)
15° b = 2.6795482′, H = 10.352781′
30° b = 5.7735027′, H = 11.547005′
45° b = 10′, H = 14.142135′
60° b = 17.320508′, H = 20′
75° b = 37.319721′, H = 38.636292′

Elevation of 15′ = a
Internal angle ∠b (Camera down angle)
15° b = 4.01932224′,H = 15.529172′
30° b = 8.660254′, H = 17.320508′
45° b = 15′, H = 21.213202′
60° b = 25.980762′, H = 30′
75° b = 55.979584′, H = 57.95444′

Elevation of 20′ = a
Internal angle ∠b (Camera down angle)
15° b = 5.3590963′, H = 20.705562′
30° b = 11.547005′, H = 23.09401′
45° b = 20′, H = 28.28427′
60° b = 34.641016′, H = 40′
75° b = 74.639445′, H = 77.272586′

Elevation of 30′ = a
Internal Angle ∠b (Camera down angle)
15° b = 8.0386448′, H = 31.058344′
30° b = 17.320508′, H = 34.641016′
45° b = 30′, H = 42.426405′
60° b = 51.961524′, H = 60′
75° b = 111.95016′, H = 115.90888′

Triangles can be used to estimate hard-to-judge object distances from the air (ex-crane shots).
H = object distance
a = camera elevation
b = horizontal displacement

Figure 2-16.

Try to borrow from all other focus scenarios. On wider lenses and larger T-numbers, remember depth-of-field zones. If you've already done three-tiered arc moves with marks, the different-colored tabs are good for any diagonal arc moves, up or down. Practice a move, or at least your focus, as much as you can. If the operator's looking through the lens, you'll distract him, so you can't physically practice your focus. Visualize the move step by step in your head. It works. You'll find the move will become more of a learned response. According to learning theory, visualizing the move means that you are rehearsing, storing, recalling, and performing. Verbalization of each step performed increases accuracy of each step performed from 50 percent to 70 percent. Chances are the operator will want to rehearse the move too. You should rehearse constantly until it's time to shoot, or until you feel you have it down. Crane moves can be a bear, but at the same time they can be very satisfying.

BEFORE PULLING FOCUS

"Have you gotten your marks?" the AD asks. "Are you guys ready? Great." Before you can answer, he walks off. "Okay folks, here we go..." It'll take him a minute to get everything going. This is an important, or at least a valuable, time for you: the time before the shot, before the focus pull.

Now is the time to run everything. Go over in your mind everything you have learned about the shot when you watched rehearsal, saw the shot, set and made marks. What deviations were there? A common automatic brain mistake is to forget this point. It seems to become a magical assumption that when the camera is switched on, ideal circumstances will prevail. Hopefully, the take will be a bit better than the rehearsal. Is talent a pro or an amateur? Professionals warm up to a peak through repeated takes. Amateurs usually stay the same or get worse. Did talent sit straight or slouch? Is talent "all over the place" when they get up from a chair? The operator will be muttering about this one too.

In the last few seconds before the shot, relax. Clear your mind for a second. Deep breathing is good here. Here's one final trick if you're tense over a complex move. Place your thumb, exerting pressure, into the hollow at the base of your skull. Put your other hand over your first hand. Your arms and elbows are at head height. Take a deep breath. Then exhale deeply while bending forward from the waist and bringing your elbows together. This is very clearing and focusing, if you'll pardon the expression. Now you're ready to pull focus.

PULLING FOCUS

Conventional Techniques

Focus pulling can be simple or very elaborate. A simple twist or accompanied by use of visual aids; assisted focus with other people and radios; remote focus and other special techniques; and even a few tricks can make up a focus pull.

Let's start with the simplest and most organic. Your hand twists a bare lens. This occurs often in sports or documentary situations, where guerrilla filmmaking is the order of the day. A follow focus would be used on bigger projects, where there is more time for setup and minimal camera configuration is not of such great importance.

Focus (Pulling) Aids

Visual aids can assist sighting and focusing objects at greater distances. A prime example of this is shooting race cars coming toward you down a long straight stretch of track. Depth and distance perception at longer ranges seem to be mediated differently than at close range. This is why some form of visual enhancement for the focuser becomes useful here. Binocular cues are less important at longer ranges, compared to shorter ranges. The effect of depth produced by binocular parallax diminishes beyond certain distances. For objects at close range, the separation of the two eyes is enough to produce parallax, or visual disparity between the two images on each retina. For objects far away, this retinal disparity becomes too small to be an adequate stimulus for seeing depth. To the eyes, images appear practically identical. This can make landmarks useless. The diminished effect of binocular parallax makes it impossible to tell if an object is behind, passing, or in front of critical landmarks.

Use a spotting scope. An 8 (eight-power) monocular accentuates differences of distances. It creates a perception of changing small angles to large wide angles. It is small angles of distant objects sighted that appear to be parallel angles or lines. Thus the angles subtended appear equal and objects subtending them appear at equal distances. This makes the judgment of varying depth and accompanying object distances impossible. A spotting scope overcomes this. It also enables you to pick out different objects, such as cars, by numbers or appearance. It also enables you to see more like the operator, looking through the long lens, is seeing. This is an obvious plus.

Video assist also allows you to see as the operator is seeing. This allows the assistant to know what to focus on in tight shots. A good ex-

ample of this is "table top," with or without snorkel lenses. Another automotive example is car commercials. You're doing running shots, car to car and the operator is "massaging" different parts of the car. Again the application here is obvious.

Assisted Techniques

A second assistant can be of value in a focus pull. He or she can walk next to the object and indicate with radio or hand signals as the object passes focus landmarks that the focuser can't see or can't judge the relative position of due to distance parallax. As the focuser you have to watch the assistant and the lens. Sometimes this isn't possible.

One solution to this problem is not to look at the object to be focused at all. Instead, the second sights the object from the camera, with or without a scope, or from next to the object. The second and you have numbered landmarks and their corresponding marks on the lens. As the object approaches and passes landmarks, the second calls out their numbers as you look only at the lens and pull to the corresponding marks on the lens. Often a cadence such as "And one... and two... and three..." increases the accuracy of the focus puller's timing. This allows the focus puller to roll between marks during the "and" and to be at the mark when the number is called. It's a timing thing.

Another form of assisted focus is useful in studio close-ups. The second takes a sight line of an actor's facial plane. This is "zero." Then as the actor's face moves in front of, through, or behind this imaginary plane, the second assistant indicates this by holding his finger X inches apart. He indicates planar position by assigning one hand to "behind the plane" and the other hand to "in front of the plane." If the actor is "dead on" his mark, the second assistant holds the fingers of one hand, or the other, tightly together.

Special Techniques

Focus can be "hands on" or "hands off"—the lens, that is. Remote focus is necessary on snorkels or other remotely operated camera mounts. Focus controls can be "hard-wired" or wireless and done by radio. The latter is of course used with Steadicam and Panaglide systems.

Focus pulling in some forms is a technique unto itself. The focus whips on "wild" hand-held cameras are a good example. The operator moves and/or holds the camera in such ways that you can't see the lens. This treatment will overcome your handicap. Find your most critical mark. Place a big, highly visible tape arrow on the lens. Set the lens to

it. Now attach the whip or grab the whip handle in such a way that a thumb or finger points in a very recognizable direction, say to 12 o'clock (straight up). Nine o'clock or 3 o'clock works well too. Six o'clock (straight down) is very uncomfortable. Now every time your finger points in the preset direction, you can know you are on your mark. This works well for up to three focus marks on a lens, follow-focus disk, or whip handle. If the operator's moves are extremely violent, the use of a whip can be dangerous and at best impeding to the shot. Mark the focus disk on the follow focus. You may still have to let go of the knob from time to time.

The focus pull, any focus pull, is an event unto itself, over time. Think of the pull in an overall, or molar way. Rather than just twisting the helical lens mount to a series of discrete marks, think of the pull, from one end of the event to the other, as an organic whole. If the object distance is changing at a fairly constant rate, the pull lies more along a segment of a continuum. The optical and physical mechanics of lens function (focus) dictate a speed change in the pull that is exponential, not linear. This means that the speed of your physical pull is either accelerating or decelerating. If object distance is decreasing, pulling speed increases. If object distance is increasing, pulling speed decreases. There is an analogous relationship between range size at distance to separation of lens focus etchings that helps dictate speed of pull. Range size at great object distances appears small. The distances per unit of measurement etched on a lens corresponding to great object distances are separated by physically small distances on the lens. At great object distances, range size appears small; lens etching separation is small. Range size at small object distances appears large; the distances per unit of measurement etched on a lens corresponding to lesser object distances are separated by physically greater distances. At lesser object distances, range size appears larger; lens etching separation is greater. An object approaching from great object distances will cover a range of considerable distance, although the apparent range size at great object distances appears small. The object's movement appears slow. The lens etchings are closer together, so you twist the lens slowly. You don't need a lot of speed to cover the physically small distances between lens focus etchings. An object approaching the camera from lesser object distances at the same speed as before will cover the same distance, although it will appear to cover a range of considerably greater size. The object's movement appears to be faster. The lens etchings are farther apart, so you twist the lens more quickly. You need more speed to cover the physically greater distances between lens focus etchings.

Tricks for Extreme Situations

The final section on technique in this chapter could almost be called a collection of tricks. But the word takes away from their value as valid solutions to focus pulling problems that can and do occur. These techniques range from the mundane to seemingly quite Zen. Most important, they all work well, are easily learned and practiced, and are quick to use.

Simultaneous zoom and focus often is quite easy. Sometimes, however, because of speed or complexity of the move, it's hard to hit marks exactly on focus and zoom collars of the lens. Use a tape stop on the zoom. The tape "stops" the zoom on its mark as it is pulled taut by the rotation of the zoom collar. Focus can almost always change. Frame size almost never changes. Given a choice of which to use, a tape stop on the zoom collar is almost always the best. Use paper tape. Cloth tape stretches.

On a combination zoom and focus, there may be a second zoom after the first. This negates the use of a tape stop. Your problem is doing two things at once. Your solution is to find a way to be able to concentrate on one thing at a time, while actually performing two functions at one time.

The key here is dividing your attention on a priority basis between the two simultaneously operating functions. Let's start with a "pull back" (zoom out). As you decrease focal length, depth of field becomes larger and less critical. You are starting in tight, where depth of field is less. Focus is more critical at the beginning of the move. Start focus and zoom at the same time. After depth of field increases, as the frame widens, you can let focus lag slightly. Pay greater attention now to the zoom. As you let it come to rest on your "out" mark, now turn back to the focus. Pull focus the remaining amount to its appropriate mark if it's not there already. You're now free for the second zoom move. If, on the zoom out, object distance is increasing, depth of field is increasing, because of this as well as because of decreasing focal length. In this case the parameters of the lens make this situation the most forgiving.

Zooming in increases focal length and decreases depth of field. On your first zoom mark, at the wide end of the lens, focus may not be so critical. Your second zoom mark, at the longer end of the lens, may dictate critical focus. So, while still on the wider end of your move, start changing focus and zooming at the same time, but "roll focus" ahead of the zoom to the second mark. With focus set, you can turn your attention to landing the zoom on its second mark. You're now free to make your second zoom move. If, on the zoom in, object distance is decreasing, depth of field is decreasing, because of this as well as because of increasing focal length. In this move the parameters of the lens make this

case the least forgiving. Of the four possible combinations of zoom and focus, object distance seems to be only slightly more critical to depth of field than focal length.

Heuristic and Cybernetic Techniques

A combined move could be easier if you didn't have to look back and forth between zoom and focus. Suppose you didn't have to look at the focus marks on the lens and were still able to pull focus to exact points (lens focus marks). You'd be free to concentrate on the zoom.

You can pull to between three and four discrete lens marks and hit them exactly, without looking. This is Zen. It's really just cybernetics. Your brain and body are in constant communication about where your body is in space. Your brain can learn quite quickly (in a few trials) to repeatedly reposition itself to fairly exact spatial locations. How do you do it? You just start doing it. But there is a "best" way to start.

Teach your body and brain where your hand is oriented in space by teaching your body a motion to repeat or a position to "refind." Hand orientation can apply to its position on a lens, follow-focus disk, or focus whip handle. Actually, in teaching yourself a "blind pull," you're learning to repeat a motion, repeat a position, and refind a location. First, put a mark on the lens, follow-focus disk, or whip handle. Align it to the witness mark. Now feel how (where) your hand is, and even look at it. You don't really need to look. Your brain already knows. But, if it will make you feel better, go ahead. After all, it is one more piece of information. In the pull you'll not be using visual cues, but hey! You're an "assistant." You're visually oriented. Now, if you've been looking, look away. You've just calibrated your hand and brain to a "zero" point. Now, without having removed your hand from the lens, follow-focus disk, or whip handle, turn the lens or disk away from the mark. Now, still without looking, twist it back to the mark. Now you can peek. Did you hit it? You can often do it on the first try, or at least get it close. Even if you got it, you must repeat the trials to get consistent, so repeat it a lot. You must make this what is called in psychology a "dominant response." If you only try it and get it once, it was most probably a chance response. Your behavior and responses change when the camera is switched on. In social psychology this is referred to as performance-oriented behavior. An "audience" increases the dominant response. An "audience" increases the stress level. The camera in its "run" mode serves as an "audience" even to you, in that your stress level is increased. Increased stress levels enhance the dominant response (hitting the mark). For the first few practice trials, watch the lens. Your eyes will tell your body when to stop. During this your brain will encode, or learn, the proper amount of twist (motion) and orientation

(position/location) correctly, the first time. Watching the lens at first avoids errors and faulty information being sent to the brain for learning. This prevents encoding faulty data, which according to learning theory must be "unlearned." This process requires conscious effort and, of course, more time.

To ease learning further, design the twist (positionally) to be "brain obvious." Orient your hand so that when the lens is on its mark, your thumb or finger (or something) is in a distinctive position/orientation. Let a digit point straight up or at 3 o'clock or 9 o'clock. These positions seem to be easily recognized by the body and easily refound, positionally. But this is bodily recognition of location and position. What about degree of movement?

Your body can learn and re-create not only position/locations, but also varying degrees of motion between position/locations. In fact, one way it finds a location is by knowing how long to "travel down a road" to get there. Focus pulling implies multiple focus points, which represent multiple locations on the lens. These locations are separated by the various degrees of motion required to twist the lens from one point (position) to another. Recognizing a repeated position or orientation of a hand (body) serves as a cross-check for the brain in confirming its proper position to itself.

Time × Motion = Location/Position

Let's take three points on a lens. Put one of the three points on the lens opposite the witness mark (index etching). Put your hand on the lens or follow-focus disk. Your brain is now taking notes. To make it easier (brain obvious), I might orient my hand to, say, 10 o'clock for one end (outside) mark, about 12 o'clock for the middle mark, and about 2 o'clock for the other (outside) mark. The remaining marks will actually dictate positions for the hand after you pick a position for the first mark. Now twist to each mark. Return to the first mark. Leave your hand on the lens or the follow-focus disk! If you reposition, you recalibrate. New position, new calibration. Twist with eyes closed. How did you do? For each point (location), your brain has assigned a position (body orientation). Also, your brain has measured and coded the distance between each point/location. Mentally, you've given your brain enough information to draw a little cybernetic map of the focus points on the lens.

Point/Location = Position/Orientation = Time/Distance × Motion

As you're twisting (traveling), your brain is saying, "Well, I've been traveling (twisting) about the right amount of time (distance) and I'm

(body) just about in the right position/orientation. So I should be just about there (location).

As well as for combined zoom/focus moves, this technique serves well in situations that offer little, if any, chance or time to look at the lens. The operator may constantly block your view. You may be shooting a complex blocking and by the time you look from actor to lens, and change the focus, you look back and the actor has moved to another point and you're out of focus. Extremely fast moving objects may move past focus landmarks way too fast for you to visually confirm the lens focus correspondence to object focus. This technique demonstrates that pulling can be a timing event, as well. As this technique relies partially on distance between points, it is true that, in the physics of our world, a certain amount of time is required to travel between points separated by a certain amount of distance.

Distance = Rate × Time, or
$D = R \times T$, or
$T = D/R$

Remember the value of timing in all pulls, whether blind or conventional. This goes back to seeing the pull from a molar perspective: as a whole.

OBSCURE FOCUSING GAGS

Little Triangles All over the Floor

The 45-degree rule works well in a rough, seat-of-the-pants-style focus pull. A good application is a shot with camera dollying right down on the deck (floor). You walk next to it focusing an extreme POV of feet, for example. It's simple in concept, quick to set up, and serves as a good rough focus check in very "down and dirty," seat-of-the-pants-style shots. It's related to blind pulling, and blind pulling can and sometimes must be used here. But the 45-degree rule pull finds its origins in trigonometry. I give it this name because it uses a 45-degree sighting angle to establish a baseline object distance to compare the subsequent focus to.

Here is the concept. In deriving trigonometric functions from the "unity circle" (a device for proving trigonometry functions), the following relationships can be seen. First, a definition. The tangent of an angle is the ratio of the side opposite an angle to the side adjacent to the same angle. See Figure 2-17a and b.

Tangent = Opposite side/Adjacent side

(a) When $\angle > 45° = \dfrac{< \text{opposite side}}{> \text{adjacent side}} = \tan\ \angle < 45° < 1$, opposite (object distance) is less than adjacent (eye height) tan $< 45°$ (focus short of mark).

(b) When $\angle > 45° = \dfrac{> \text{opposite side}}{< \text{adjacent side}} = \tan > 1$, opposite (object distance) is greater than adjacent (eye height) tan $\angle > 45°$ (focus past mark).

(c) When vertex $\angle = 45°$, $\dfrac{\text{adjacent side}}{\text{opposite side}} = \dfrac{1}{1} = 1$, object distance = eye height (focus at mark).

Figure 2-17.

You'll sight the object as you stand at (above) the camera.

Now, from the math we see... See Figure 2-17c.

What does this diagram mean? Let's take the last case first (c). Standing at the camera, sight the floor by looking down at an angle of 45 degrees. The sight line from your eye to the object, a line from this projecting back to the camera, and a line from the camera back up to your eye form a rough isosceles triangle.

The two legs of the isosceles triangle are equal. This means that object distance equals your eye height.

Tangent of Angle x = opp/adj = X/X = 1

So,

Tangent of Angle 45° = 1

For any fraction or ratio to equal 1, both numerator and denominator must be equal. Numerator (opposite side) = object distance. Denominator (adjacent side) = eye height.

The 45° Rule for Focus: Establish a rough following distance. This will be the object distance. Sight it at 45 degrees and measure your eye height. This will equal object distance. Mark this with an arrow on the lens. As your sight angle increases or decreases, object distance is increasing or decreasing. You can know from this that you should be "past," or focused farther than your tape arrow; or that you should be

"inside," or focused closer than your tape arrow as object distance varies. See Figure 2-17 a and b.

In summary, here is the setup and technique. The beauty is that you can put just one mark on the lens and start shooting. Your sighting angle will determine if you should be on your mark, past it, or inside it.

The Technique: Establish an average (rough approximation of) following distance (object distance). With the camera on the floor dolly (at object distance), and your hand on focus knob, find an eye height at which you can sight-focus the object at 45 degrees. Your object distance and eye height are equal. Let's take, for example, an object distance of 3 feet.

Tangent angle 45° = opp/adj = (=/=) = 1/1 = 1
Opposite (object distance) = adjacent (eye height)

Mark the lens with this distance (one arrow). During the pull, when you sight down an angle less than 45 degrees, you know that the object distance is less than eye height (3 feet), so object distance is less than 3 feet. Pull "inside" your arrow mark at 3 feet. See Figure 2-17a.

On the other hand, when you sight up at an angle more than 45 degrees, you know that the object distance is more than eye height (3 feet), so object distance is more than 3 feet. Pull "outside" your arrow mark at three feet. See Figure 2-17b.

Geared Heads as Focus Aids

Focus cues from a geared head? A geared head is an operator's tool. Operators don't focus, they operate, but a geared head can help you by providing focus cues. Tabletop close-ups with no video assist are rare these days. Still, times arise when you need to know what element is "filling the frame" in close-up, so you can pull focus to it. What to do? Use your head. The knobs on the pan and tilt wheels of a geared head will indicate, by their position, where the camera is pointed. This tells you what object to focus on—easy.

Talent as a Focus Aid

Let people you photograph help your focus pull. Study an actor's stride. Is he doing a lot of walking toward or away from you? Can you get a chance to measure his stride? Now, "in shot," count his steps as you pull.

Six 3-foot steps toward you should have you focusing approximately 18 feet closer on the lens.

Using talent for cues also helps with "timing" kinds of moves. An example of such a move would be a quick rack focus in something like a confrontation for a gunfight. You may be required to rack focus quickly from one actor, as he turns, to another. If their action is fast, it can be quite difficult to get it. You'll often be late. What is the solution? Often people perform some cue-like behavior just before they perform a particular bit of business. And more often than not they will repeat the behavior every time, before the "gag." Use this as your cue if you can notice it. It may be as subtle as a muscle tensioning (a hand squeeze on a bar rail). It may not be noticeable at all. If this is the case, a lot of actors are quite willing to work out a little "pre-cue" gag with you. Just ask. "Okay kid, I'm going to rock back on my heels just before I turn."

Crossover (Reversed) Focusing

The left camera is focused with the right hand, and the right camera is focused with the left hand. Why? This sounds like a circus trick—a circus trick that would never be necessary, with huge potential for confusion and mistakes, and would serve only the purpose of getting you fired. Actually the need does arise. It's not a trick at all, and it's not difficult. Imagine this. A conversation between a driver and a passenger in a car. To save time we'll get matching, over-shoulder close-ups with two cameras, rolling simultaneously. The limited space in the back of the car allows for one operator and one assistant. The other camera is locked off, but its close-up requires follow focus. You hand-focus one camera, and to focus the other, you must use a remote focus. The cramped space only allows you to squeeze in with arms crossed. Your hands are crossed over to the focus controls. You must be inside the car because you have only one remote focus. This has happened to me, and I know I'm not the only one.

This is completely doable. So don't worry or be flustered by the task. This will only impair your concentration. It turns out your brain is capable of "switching" over in a very short time. It's like speaking a language. Your brain doesn't consciously translate from object to English word meaning to new language word meaning. It thinks object to new language word. By the same token it doesn't translate from right-side camera: not right hand, but left hand, and vice versa. Instead it thinks object focus directly without conscious regard to which camera is being controlled by which hand. The brain eliminates intermediate steps.

So just start focusing. It works and feels just like focusing in a con-

ventional manner. The important point of this treatment of this subject is to know going in that you can do it. And that you can do it easily. Avoid deadly hesitation. Rather than acting like there might be a problem and/or show lack of self-confidence, you'll just say "Fine" and go do it. No fretting. No whining. You won't take too long setting up because you're rattled. If you're convinced you're going to mess up, the greater the likelihood you will mess up. So know this is no big deal. It looks like a big deal, and you'll look like a hero and impress everyone with your cool, calm, and collected manner.

THE RIGHT AMOUNT—THE RIGHT SPEED—THE RIGHT TIME

While we're were on the subject of no jumping overboard, this is a good time to discuss this as an element of focus itself. Don't overdo it. Don't overfocus. Don't focus too much. Don't focus too fast or too soon. Focusing a lens actually changes the focal length of a lens. This is what we experience as a zoomlike breathing in a prime or zoom lens. Follow focus, but take advantage of depth-of-field zones to minimize pulling. Don't twist too abruptly. It's distracting to the operator, and it looks bad in the shot. Let the subject begin to approach the edge of the focus zone before moving the zone. Begin a slow pull. Imagine moving a little cloud to keep it surrounding your subject. Finally, don't focus too soon. Objects approach the lens from infinity. As they start toward you, let the lens at first just rest there, on infinity, for a moment. After all, this focus setting establishes your second-largest depth-of-field zone. Assistants tend to routinely focus in front of fast-moving objects. Keep this in mind. Shortening lens focus early shrinks depth of field early. So leave it as big as possible for as long as possible. Let it become a little Zen. Some assistants talk about almost letting the object "push" focus. You can think of it as the object gently pressing on an invisible membrane that is the focus zone. It may sound silly. It does sound silly. Still, most assistants, operators, and DPs that are "around it" will seriously maintain that there is a certain "feel" to focus pulling. "Go with the force, Luke."

After Pulling Focus

"Cut! Did we get it?" the AD asks. The director liked it. Talent feels good. The operator isn't frowning. He turns to you. "How do you feel, good?" This is not the time to start crying. "Sure. Fine," you answer quickly.

Everybody's happy. We'll shoot a few more, see if things get any better, and get a safety for the lab.

SHOT CONFIRMATION: WAYS TO CHECK AND GUARANTEE SUCCESS

There are ways to assure "keepers." This lies in ways to check for success. In a very tight shot, where focus is critical, right at "Cut," someone (you) says, "Freeze for focus!" The object or talent is held in the last position. You may quickly extend a stiff tape measure if the object is close enough. Is it in depth-of-field range? Is it on its mark? Are you on your mark? A visual check may be done. The aperture is opened, and the operator may either judge focus or refocus the lens. He'll then ask if his focus is the same as your focus.

"Is that it?" It either is or is close enough (be careful here), or it isn't. If it's close, you must know if the object distance you focused the lens to yields a depth of field that encompasses the object's actual object distance. Either it does or it doesn't. So this eliminates the mistakes made by gray areas. It's either in zone focus or out. If it's right on the edge, ask for another. Don't be afraid to be afraid. Call it conservative. Bravado doesn't count for much in ruined dailies. You have the choice of a few extra minutes for a few extra takes or a reshoot at premium prices. If it's the latter, believe me you won't be invited.

VALUE OF INDIVIDUALS' JUDGMENTS

Finally, if your second assistant was watching talent and signaling "position to plane of focus" to you, you can ask him or her. Did they see talent "all over the place" or were they pretty right on? Compare this to your impression, then check the "butterfly coefficient" in your stomach.

Remember, you are an important judge. The operator can't always see, for reasons mentioned earlier. Shutter fatigue, or just the absorbing task of operating and composing, disallows him time or presence of mind to truly see focus (operators don't like this).

This works both ways. Sometimes an operator will say part of a shot was soft when it wasn't. This is especially true of very chaotic, fast-moving shots. An example would be cars speeding by you (especially if he has to swish pan them). At short object distances, focus is most critical and error potential is greatest. Also, the shot is "working" its fastest and the operator is most distracted. Don't be afraid to maintain that all

or much more than reported was indeed sharp. You must feel strongly about this. If the director is confident about you, this input is meaningful to him. It makes him feel better and maybe he can move on to squeeze in that last extra "pet" run-and-gun daylight shot he had in mind.

We've looked at a body of organized knowledge that covers processes taking place before, during, and after the shot. You now have a collection of rigorous techniques. They cover estimating short, medium, and long distances, based on conventions found in nature, the science of learning psychology, and the mathematics of trigonometry. We've outlined mark-making systems designed to minimize confusion and speed setup. We've outlined focus setting techniques. We've examined factors that interact with perception of focus.

We've discussed focus pulling in conventional situations and specialized techniques. We've discussed seeing with our bodies and not our eyes: very Zen. This augments performing zoom and focus moves. Last, we've talked about confirming successful performance. Next we'll take this show on the road. We'll discuss adaptation of all or part of the above knowledge and procedure to different shooting situations.

3

On the Road

DIFFERENT APPLICATIONS OF TECHNIQUE FOR DIFFERENT SHOOTING SITUATIONS

Shooting motion pictures varies in form, procedure, and technique as widely as does the subject matter, the shooting situation, and the location. Motion-picture production falls into two basic categories: dramatic and documentary. You could break this down ad infinitum: features, docu-features, commercials, info-mercials, educational films, informational films, corporate, music, and sports.

Motion-picture production takes place in basically two places: the studio and the field, or location. To both milieus we will apply the concept of guerrilla filmmaking. This concept applies more widely to field operations. Still, guerrilla techniques offer valuable benefits in a studio setting, as well. An example will be speed work with a second assistant. In the field we'll examine speed without a second assistant. Stripped for battle we'll look at equipment consolidation and special ditty bag setup for moving fast in a firestorm. We'll address minimal camera configuration and "hot camera setups" for speed, a term borrowed from car racing. Sports, especially car racing, are venues that are particularly well suited to guerrilla techniques. We'll look at shooting in stadiums using man-made features for focus. Finally, we'll go through a series of examples of long-lens focus pulls. Let the battle begin…

FOCUS SEQUENCE

The focus sequence is a flowchart made up of the elements of focus setup, preparation, and execution. Various elements are deleted or in-

cluded as they apply to various shooting situations. Let's look at the focus sequence at two ends of the spectrum. Treat everything else as variations along a continuum. Dramatic production, in studio, represents the full scenario. It is the most procedural in terms of the operations performed. At the documentary end, the most bare-bones example is probably sports. It's a form of extreme documentary. It almost invariably takes place in the field. It is least procedural. At the same time, sheer technique becomes most critical.

Let's look at the example flowcharts of the focus sequence for shoots that differ in level of production from full-dress dramatic/studio production to bare-arms (mano-a-mano) sports in the field. See Figures 3-1, 3-2, and 3-3.

KINDS OF SHOOTS: DRAMATIC, SPORTS, DOCUMENTARY

The most complete example of the focus sequence applies to dramatic production. (Sorry, you wanted to do this.) In a classic dramatic production (including commercials), the 1st cameraman, or director of photography, is the head of the entire technical crew. Being near the top of a tree with many branches, he obviously has a lot of power. He is deferred to a lot and is given large consideration. I mention this only to contrast this position with that of the documentary cameraman. The feature DP photographs highly staged elements that tell a story that never really happened at all.

In the documentary, the cameraman who records the event as it actually happens is often given absolutely no consideration at all. Documentary cameraman at some times, in some unions, has been considered a separate category. He is rarely the seasoned older gentleman, accomplished in his art. More often the documentary cameraman is a young kid scrambling for a break. He is not the high-paid eagle atop a tree, rich in green leaves of money. The documentary cameraman is not the head of the entire technical crew. Often there is no crew. Maybe a soundman, maybe not. Maybe an assistant, maybe not. (The assistant's off shooting somebody else's documentary somewhere.)

Look at the focus sequence flowchart for the documentary/sports scenario (Figure 3-2). This is for a three-man crew, not a hundred-man crew. This crew consists of a cameraman, an assistant, and a soundman. Here roughly 20 percent of the operations are not boxed and labeled as SOMETIMES NOT AN OPTION. There is not enough time for the small crew to work through all the operations. There are not enough bodies for all the equipment. There is not much of anything because there is often

- **Before focus →** Elements to study
  - Talent's movement
  - Visualize shot
  - Relax
- **Before pulling →** Establishing
  - Estimate → Trig → Short
    - Medium
    - Long
    - Natural conventions
    - Man-made conventions
  - Measuring → Lens focus
  - Eye focus → G. G. focus
    - Film plane focus
  - Making marks → Multiple techniques
    - Multiple mark designation
    - For focus crossover → Two-directional object movement (approaching and receding)
      - Identical and/or symmetrical object focus and identical lens focus for different camera
      - Circular dolly
      - Complex crane focus
- **Pulling focus →** Conventional techniques → Lens twist
    - Studio follow focus
    - Remote focus
  - Focus aids → Spotting scope
    - Video assist
  - Special techniques → Heuristic pulls
    - Cybernetics
  - Assisted techniques → Use of 2nd assistant for focus cues → Visual
      - Aural
  - Nonconventional techniques for extreme situations → Hand-held
    - Rough pulls
    - Clock-face marks
  - Tricks → Multicamera focus
  - Focus and zoom → Simultaneous without tape stops
    - With tape stops
    - Cues from geared heads
- **After pulling focus →** Judge and retake
  - Freeze and recheck ground glass focus
  - Ask assistant
  - Ask operator
  - Reshoot

Figure 3-1. Full scenario, possible in studio/dramatic, large-scale production.

- **Focus →**
  - Before pulling
  - Establish focus →
    - Estimate →
      - Trig →
        - Short
        - Medium
        - Long
      - Natural conventions
      - Man-made conventions
    - *Measuring →*
      - Lens focus
    - *Eye focus →*
      - G. G. focus
      - Film plane focus
    - *Making marks →*
      - Multiple techniques
      - Multiple task designation for focus crossover
      - Two-directional object movement →
        - Identical and/or symmetrical object focus and identical lens focus and identical camera locations
        - *For circular dolly track*
        - *For complex crane moves*
- **Pulling focus →**
  - Conventional techniques →
    - Lens twist
    - *Studio follow focus*
    - *Remote focus*
  - *Focus aids →*
    - Spotting scope
    - Video assistant
  - Special techniques →
    - Heuristic pulls
    - Cybernetics
  - *Assisted techniques →*
    - *Use of 2nd assistant for focus cues →*
      - Visual
      - Aural
  - Nonconventional techniques →
    - Techniques for extreme situations →
      - Hand-held
      - Rough pulls
      - Clock-face marks
      - Clock-face hand positioning
    - *Techniques for specialized situations →*
      - Remote head shot (see conventional)
  - Tricks →
    - *Multicamera focus*
    - *Focus and zoom →*
      - Simultaneous without tape stops
      - With tape stops
    - *Cues from geared heads*
- **After pulling focus →**
  - Judge →
    - *Retake*
    - No retake
    - *Freeze objects* — Recheck G.G. focus
    - Ask assistant — *Asks 2nd*
    - Ask operator — Asks assistant
    - *Reshoot*

Note: *italics = sometimes not an option*

Documentary/sports scenario.

Focus = Before pulling
No before possible
Delete all pre/setup operations

Nonconventional techniques → Extreme → Hand-held
Rough pulls
Pulling (on fly)
Estimate → Trig → Short
Medium
Long
Natural conversions
Man-made conversions
Special techniques → Heuristic pulls
Cybernetics
Pull only → *Assistant*
Operator

***After* pull** → No retake
Move on

Note: *italics = sometimes not an option*

Figure 3-3. Extreme sports/documentary.

not much money either. The operations that do remain are more technique oriented and less procedural. This is because the events unfolding in a documentary present themselves in such a way that they are happening to you. To accommodate this requires technique, because you are not creating the events. You cannot predict or structure them, so there is no framework on which to hang an elaborate (and tedious) procedure.

Look at the final version of the focus sequence (Figure 3-3). This is a true firestorm paradigm. This mostly applies to production (better called shooting) of news and sports. Sports, especially, can be documentary in its extreme form. The focus sequence is maximally stripped down to its bare bones. Items under "Before Pulling Focus" and "After Pulling Focus" have been italicized as SOMETIMES NOT AN OPTION. Only about 5 percent of all operations are possibly executed. Like the event to be documented, the shooting exists only in the pure instant of the moment. There is kind of a stark beauty to this idea, a simple grace. There is no procedure, which implies planning. Here only sheer technique applies, which is used to grapple with assailing variables during execution. Look at even the shape of the structure that is artificially imposed on the focus sequence at each level of production. Dramatic

shooting occurs at the highest level of production. It is multilayered and very tertiary. Extreme documentary shooting is the simplest. It is completely linear, with no parallel operations occurring. As you move from the highest level of production to the lowest, things become less horizontal and more vertical. Things are laid out less end to end. Things just occur at once. The orientation is less procedural and more technical. Notice in the most extreme form even the assistant (Gasp!) is boxed as SOMETIMES NOT AN OPTION. In the words of a producer who reminded me a lot of Gumby, "Everyone is erasable!"

But there is a lot to be looked at, seen, and discovered (Zen) in this minimalistic (Zen) paradigm. How do we become indispensable? By being blindingly fast and becoming a "rat bastard" focus-puller. Do I see point lights of desire burning in those beady eyes? Step right this way . . .

Always in some kind of shooting an assistant will be considered only as an option. However, even here some kinds of assistants will be considered more favorably as a benefit, not just an option. If you want to work more, you want to be this kind of assistant. An assistant who stands firmly on procedure, even thoroughness to the extreme, will find he is presenting himself at odds with production, the director and even the DP. This is true even in the most formal studio situations. Ultimately everything, even everyone, is secondary to *GETTING THE SHOT.*

Just about everything will be sacrificed for this. No one cares how neat the camera reports are if the money shot isn't in the can and the sun's going down. An extreme example of this sacrifice is pushing equipment to its limits and past. Insurance companies and rental houses won't like this next bit of text, but economics can create certain dynamics that on general perusal aren't a pretty sight for the squeamish. An Arriflex 35 III has a recommended top speed of 120 f/s (frames per second). Most camera bodies are capable of an absolute top speed of about 135 f/s. I say *about* because, at a camera's absolute top speed limits, it may not be able to hold constant speed even though that speed has been selected with a crystal-controlled high-speed unit. The greatest danger here is not one of speed fluctuation and losing sync or going out of phase with HMI pulse frequencies, causing light sources to apparently flicker. Crystal-locked speeds are often not a priority when the director is asking about the camera's maximum top speed. Maximum top speed is not really redundant here, because there can be two of them. One is available when pressing digitally selected speed control buttons on a CE (Cinema Electronics) base. The other maximum top speed is often quite different and quite faster. It is available when sampling speeds by turning the variable speed control knob on the CE base.

In each case the mode selector switch is set to the appropriate position. The greatest danger is mechanical damage to the camera body itself, specifically to the armature or other parts of the movement. This, by the way, can be a $5,000 repair. Not only is the repair expensive, but if you break the movement, the camera is down for the day. And if the camera is down for the day, the whole shoot may end up down for the day, or at least for a couple of hours. Remember we're talking about a commercial crew on the clock at about $3,000 to $4,000 per hour. So there are some good reasons not to exceed the top speed recommended for a particular camera body. But…

Remember, we're talking about *getting the Shot.* This is where complicating factors can simplify everything—very Zen. Quite simply, the director may not care about any of this. He wants his shot and he's the creative guy. Ultimately it's his call, and he may know exactly what he's doing creatively and to the camera. It may be worth it. The production company has insurance on the gear with a $1,000 deductible. Now it's not a $5,000 repair anymore. It's a $1,000 repair, and to him, and more important, to the client, his shot may be worth a lot more than either of these figures. If it's *The Money Shot,* it could be worth tens of thousands of dollars, even the whole shoot day, even the whole shoot. It may be the end of the day anyway, so who cares if the camera breaks? Get a new one for tomorrow morning. Just handle it, kid. The point is, if the director wants to know "How fast can we go with this camera?" give him the answer and all the pertinent information he needs to make the call. This means ask all the questions you need to about the camera's top speed when you're at the rental house on the prep day, especially if they use the word "recommended" or you think that they're hedging in some way. Though just about everything is expendable, you at least are a vital and valuable source of information.

Yes, the traditional assistant's values are important: care for the safety of equipment, care in procedure, and thoroughness are all important. Taking time to ensure these qualities is important, but taking time and ensuring these qualities past a certain point becomes counterproductive.

There is a kind of assistant that is well suited to the fast, efficient, precise discipline of shooting that I'm trying to get at here. The kind of assistant that can change camera configurations, perform film loading and magazine changes, and be ready for each new setup with accuracy, speed, and precision is the kind of assistant that delivers in a way that is in harmony with the bottom line. The bottom line is "get it as fast and cheaply as possible and have the photographed product be of the absolute highest quality. Production wants it all. Try to give it to them. They want the best they can get, just like the director and the DP. How-

ever, fastest, cheapest, best is what everyone (who's important) wants to approach. The kind of assistant who aligns his own priorities and performance to approach fastest, cheapest, best is the assistant who is worth the most money. What kind of assistant is this? This is the guerrilla assistant and this is guerrilla filmmaking.

GUERRILLA FILMMAKING

Guerrilla filmmaking applies to formal studio production and stripped-down field shooting. Like the name, its applications are somewhat greater in field/documentary kinds of shoots. We will look at both ends of the spectrum. First, let's borrow from the dictionary definition of the word *guerrilla*, then elaborate on the guerrilla concept as it applies to filmmaking. Guerrilla: 2a: one who carries on or assists in an irregular war ...[1]

I like this. Even the word *assists* is in the definition. The word *irregular* here is important. I want the guerrilla assistant to do everything better by being a little different. To acquire (higher excellence) we must shed or sacrifice. To gain a lot, we must lose or strip off a little. This is Zen.

The guerrilla concept embraces sacrificing a little orthodoxy. We'll sacrifice some procedure. We'll risk and sacrifice some degree of safety. Equipment handling may be rougher, but not beyond reasonable limits. Lens caps may not be put on as soon. Air to remove debris will be blown into the system less often. Sometimes in the extreme, film gates may be checked less or not at all. Color-correcting filters can be pulled for "more stop." Sometimes, for a documentary operator, perfect framing may be sacrificed. This happens most often in sports and news shooting. Usually, however, it's the hardware that suffers first, the software (the shot) least, if at all. If this concept is applied properly, the gear remains safe, operating and assisting is fast and accurate, and the rendered shot is of the highest caliber.

All guerrilla assistants are good assistants, but not all good assistants are guerrilla assistants. The distinguishing qualities of a guerrilla assistant differ only slightly from those that determine the conventional "good" assistant. The qualities of accuracy and precision are shared by "good" assistants. To be a good assistant, you must be accurate, but do you have to be slow? Increased accuracy with great speed distinguishes the Zen level of assisting. The Zen assistant is faster and more accurate. The adaptive value of guerrilla technique is shown in the following bit of text on heuristic problem solving.

Speed

"The human problem solver may find it desirable at times to accept some reduction in the probability of achieving a correct solution in order to maximize processing (focusing) speed. Speed is likely to be a major consideration when adaptive behavior is concerned.

Using processes that guaranteed a correct identification of a potential threat, but were too slow for an appropriate response, could be disastrous for the problem solver. A pattern recognition scheme that guaranteed that only lions were recognized as lions might seem more desirable in the abstract than one that mistook other stimuli for lions, but if the former scheme was too slow to allow a person to flee an attacking lion, the former scheme (and the person using it) would not be expected to survive.

Speed may be desirable in less dramatic instances. The problem solver may find an approximate conceptualization of his spatial environment, for example, quite satisfactory most of the time, even when there is enough information available to the visual system for a more accurate determination of the angles at which various surfaces intersect his line of sight."[2] The heuristic focus pull mentioned in Chapter 2 ("Pulling Focus: Special Techniques") is an example of this. A documentary setting with no time to prefocus is another example of this. You focus "on the fly." There are many applications of this general concept in the studio and especially in the field that may be discovered by you.

Studio Setting: Speed Work with a 2nd Assistant

Here are a few examples of the concept applied to specific procedures that occur commonly in the studio. They're a slightly radicalized version of older "accepted" ways. They take advantage of the 2nd assistant cameraman. The variations in technique allow these "hot-tuned" methods to develop a high degree of speed and precision and preserve a high level of safety for the equipment. The procedures outlined are (1) major lens changes: zooms to primes and primes to zooms; (2) major configuration changes: studio to hand-held and hand-held to studio; and (3) the "best" (fastest) reload. The procedures are described in text and "exploded" out into flowcharts.

Major Lens Changes

Zoom to Prime Lens Change

This is more than a single element-for-element trade. The *type* of lens is different. This means at least one extra case. The type and amount of

support gear are different. This also means more cases. The type and or size of filters may change. This too may mean more cases. The balance is changed. This involves a lot of procedure that can quickly turn into a fumbling circus. Develop a simple trade-off system with your 2nd assistant. The operation will move ahead smoothly and safely, the steps ticking off steadily quickly and quietly. Here it is broken down.

Anticipate: Anticipate each other, the 1st and 2nd. This is most possible if you're both thoroughly straight on the sequence of the drill. Another thing to anticipate is the request for the lens change. Know ahead when it will come. This comes from paying attention and planning. Remember, it can help to think like you're the 1st cameraman. This will cause you to think along similar lines, in terms of what possible solutions are available to make certain shots. Sometimes things cannot be anticipated, but if you're always paying attention, you'll recognize from the director or the DP's talk that a change is becoming likely. Have the 2nd assistant bring two cases: zoom and primes. You're ready. If the change comes completely out of the blue, send him for the cases, but don't wait for his return.

Begin Disassembling: Unplug the zoom motor cable. Pull the matte box (off the rods). Give it away to the 2nd assistant. If he's not back yet, put it down close to you, where it's safe. Swing away the focus gear and unscrew the support bridge. Unlock and remove the zoom lens. Give it away. Capping the camera is optional. The 2nd should be back by now. If he's not (fire him), make the lens "safe" and continue disassembling. Some assistants have put down a zoom lens on its large end (front element), but not one would admit to it. You can cradle it in your arm and continue to remove the follow focus and support bridge and rods, but this is getting a little (a lot) risky. Slide the camera to its new balance point. Do this now because the camera body is now at its lightest. Before being reconfigured to match its weight to its new balance point, it will fight the tripod head the least in its light state.

If the 2nd is there in time to take the lens that you give away to him, he "safes" it by just laying it in its case (no caps yet). The same occurs as you give away the follow focus, support bridge, and rods all at once to the 2nd. He merely "safes" them for stowing later. Operate first. Stow later.

Begin Assembling: As you give away the peripheral and support gear, the 2nd trades you for the short support (iris) rods.

The 2nd is "safing" or stowing gear. The 1st inserts the new short iris rods. The 1st then mounts the follow focus. The 2nd gets out the selected prime lens. It is "preset." The aperture should be wide open and

the rough lens focus set. The 2nd hands you the lens. Confirm the preset as you mount it. If lens choice is still an issue, skip the rods and follow focus. Mount the prime with no extra hardware. Preset the lens as you mount it. The 2nd does not preset here. This takes extra time and makes the execs wait unnecessarily while they are eager to see the lens and make a decision. In neither case does the 2nd check and/or clean the lens at this point. Engage the follow-focus gear as the 2nd assistant gives you the appropriate matte box or sunshade and retaining rings. Reconfirm use of same filters or any requests for a change. If a change is required, do this during "safe to stow" time. Fine focus as soon as you have the opportunity.

"Safe to stow" means that gear that was just laid (in cases) down on foam and/or in "safe" places, in the interest of speed, is now properly stowed. During this cleanup time everything is put away. Cases are closed and removed from the camera. If you anticipate many lens changes, the prime case should now be kept close to the camera and not back with the rest of the gear.

Somewhere in this transitional period the lens may be checked and cleaned. *After* everyone's happy. During the initial change, no check or cleaning should be done. That lens may not be chosen. It takes unnecessary time, of important people, that can be taken later. I've seen too many 1st ACs stand there helplessly as operators, DPs, directors and producers sigh, scowl, and lose their patience watching a 2nd bent over, down on the floor, squinting at a lens like some self-righteous, persnickety old lady. It really looks like an exercise in brain death. If you see your 2nd doing this, go over and take the lens away from him, mount it, and speak to him later. The point is "we *might* use this lens. Let us see it ASAP." So let them see it ASAP. The lens and/or camera can be in a totally different state than that required to photograph with it. Try to meet the big dogs' wishes as instantly as possible. Let them see it. It's always ready for this. If they like it, *then* get it ready to photograph. See Figure 3-4.

In a "look-see, just-shopping" situation, go to a "short show mode." After the zoom lens is removed, mount the prime, rebalance the camera, and give it back to the execs. See Figure 3-5.

The "short show mode" appears to be as long as the conventional sequence. The chief difference is in the operation sequence. When the lens choice is made, return to and continue conventional zoom to prime lens change sequence.

Prime to Zoom Lens Change

Again this is more than a single element-for-element trade. The *type* of lens is different (extra case). The amount of support gear is increased. The type and or size of filters may change. Anticipate.

Zoom to Prime Lens Change
Example Arriflex System

1st sends for two cases (zoom and primes)
1st unplugs zoom motor cables

2nd brings and opens cases

1st removes matte box—gives it to 2nd
OR
1st "safes" matte box
1st unscrews support bridge
1st swings away focus gear
1st removes zoom lens—gives it to 2nd

2nd "safes" lens

1st slides camera body to new balance point
1st removes long rods with support bridge and follow focus attached
1st gives it to 2nd

2nd proffers short iris rods
2nd removes support bridge and follow focus from long rods and "safes" them

1st inserts short iris rods

2nd proffers selected prime (preset option)

1st mounts prime (preset option)

2nd proffers follow focus

1st mounts follow focus
1st engages focus gear

2nd proffers matte box
OR
2nd proffers sunshade and retaining rings

1st mounts matte box
OR
1st mounts sunshade and retaining rings
1st fine focuses

Safe to Stow

2nd stows "safed" components

1st confirms filters

2nd removes cases

Figure 3-4. Zoom to prime lens change.

Anticipate the change and send the 2nd for two cases (zoom and prime). If there's a problem with bringing two cases at once (time/bad location of cases, or the 2nd has a coffee in one hand), the zoom case should take priority. It holds the next shooting lens. The prime can be "safed" in this case until it can be properly capped and safely stowed in its own case. Priority always goes to the operation that achieves the new camera change as soon as possible. The 2nd brings and opens the cases. The 1st removes the sunshade, clamp-on, and retaining rings. If we're in a real hurry, the 1st removes the lens from the camera with

Short Show Mode: Zoom to Prime Lens Change
Example Arriflex System

1st sends for two cases (zoom and primes)	
1st unplugs zoom motor cables	2nd brings and opens cases
1st removes matte box—gives it to 2nd OR 1st "safes" matte box	
1st unscrews support bridge	
1st swings away focus gear	
1st removes zoom lens—gives it to 2nd	
	2nd "safes" lens
1st slides camera body to new balance point	
	2nd proffers tentative prime choice
1st mounts prime (preset)	
Camera is ready for viewing by execs (lens approved or alternate viewed)	
1st removes long rods with support bridge and follow focus attached—gives to 2nd (before, during, or after lens approval)	
	2nd proffers short iris rods 2nd removes support bridge and follow focus from long rods and "safes" them
1st inserts short iris rods	2nd proffers follow focus
1st mounts follow focus 1st engages focus gear	
	2nd proffers matte box OR 2nd proffers sunshade and retaining rings
1st mounts matte box OR 1st mounts sunshade and retaining rings 1st fine focuses	
Safe to Stow	
	2nd stows "safed" components
1st confirms filters	
	2nd removes cases

Figure 3-5. Short show mode: zoom to prime lens change.

the shade, clamp-on, retaining rings, and filters all still mounted on the lens. The 1st hands this entire assembly to the 2nd. If a matte box is being used, it is of course removed separately and "safed" by either the 1st or the 2nd. The 1st removes the prime and gives it to the 2nd. Capping the camera is always an option. It is always a good thing, but it takes a little time. In the case of transitioning from prime to zoom, it is more highly recommended for safety. This is because the 1st will be inserting

long iris rods, which can be more unwieldy than short iris rods. There is a greater chance of pushing an iris rod through the spinning mirror/shutter. Next, the 1st pulls off the short rods with the follow focus attached (fast). He gives them away. The 2nd disassembles.

The 1st slides the camera to its new balance point. The 2nd proffers long rods and support bridge. The 1st inserts long rods and mounts support bridge. The 2nd gives follow focus to the 1st. The 2nd checks and cleans zoom lens. This is done here because the lens choice is already locked (focal length may yet be determined). Unlike a prime lens, the zoom is not easily or quickly removed for cleaning. The 1st mounts follow focus. The zoom is preset by the 1st only because handling changes lens focus on the focus collar. The 1st is the last to handle the lens, so he is the last to change the focus, so he is the last to set lens focus. If the big dogs are eager, you may stop here and let them look. Check balance if you do. It will probably not be set for a stripped lens. The 1st engages the focus gear and resets rough focus, if necessary. If no focal length has been determined, he may set a rough focal length if appropriate. The 2nd prepares the zoom control. The 2nd fixes the zoom adapter ring into matte box, if appropriate. He gives matte box to 1st. The 2nd puts rubber light gasket (doughnut) around lens barrel, if appropriate. The 1st mounts the matte box. The 2nd plugs in the zoom control and begins "safe to stow." The 1st fine focuses at first opportunity. The 1st confirms filters. The 1st or 2nd makes any filter changes. The 2nd removes cases from camera. See Figure 3-6.

The above examples of lens change procedures are merely that—examples. They are not recommended. They are suggested. They're quick and efficient because they are a system. Any system is organized. Anything that is organized is quicker than that which is not. They are standardized. They tick off the same way every time. This adds to their speed factor. Every step can be anticipated, because everybody knows what's going to happen next every time. If you can make them faster, make up your own routine. Make it better. The point is to develop some kind of routine. Even if it's just to tell the 2nd to do it. Doing this is completely valid. There may be times when there is absolutely no need at all to hurry to get the lens changed. Why waste your energy? Go get a coffee.

Major Configuration Changes

Studio Mode to Hand-held Mode

The most major camera configuration change involves taking a fully built studio system to a hand-held mode. The easiest and quickest way to do this is to have two cameras. One is constantly set up for studio-

Prime to Zoom Lens Change
Example Arriflex System

1st sends 2nd for two cases: zoom (priority) and prime	
1st removes matte box; "safes" it	
	2nd brings and opens cases
	2nd "safes" matte box
1st removes prime lens and gives it to 2nd (port cap optional)	
	2nd "safes" lens
1st removes short iris rods with follow focus attached	
	2nd disassembles same
1st slides camera to new balance point	
	2nd proffers long rods and support bridge
1st inserts rods and mounts support bridge	
	2nd proffers follow focus
	2nd checks and cleans zoom
1st mounts follow focus	
	2nd proffers zoom lens
1st mounts zoom lens (preset)	
1st engages focus gear (reset focus) (rough focal length)	
	2nd prepares zoom control
	2nd fixes lens adapter to matte box
	2nd proffers matte box
	2nd places "doughnut" on lens
1st mounts matte box	
	2nd plugs in zoom control
1st fine focuses	
Safe to Stow	
	2nd stows "safed" components
1st confirms filters	
	2nd removes cases

Figure 3-6. Prime to zoom lens change.

style shooting. The other is constantly rigged as a hand-held camera and standing by. This scenario is also the most expensive. You will see it least often.

It's important to be familiar with changing a single-camera system from one mode to the other at a level that is almost automatic. It means it's faster and more foolproof.

It helps avoid forgetting to add on certain hand-held accessories completely or remembering them late in the transition sequence. After the camera is off the tripod head, tasks and procedures are much harder to perform with a heavy object that is unbalanced. Tasks that

could be done with one or two hands might now require four. This means taking up another person's time (away from some other duty). It slows the whole process down. So familiarity speeds things by its nature (Zen word). You can work with greater speed and accuracy. This is particularly true in major configuration changes, because there are so many things to think about.

In a major configuration change, you're basically unrigging an entire camera system and building an entirely new one that is most often entirely different. This is a textbook of sorts, so I'm going to describe a textbook scenario.

The ideal situation starts with two camera platforms. On one rests the fully built studio camera system. The camera platform will most likely be a geared tripod head, or it could be a fluid head. Either will most probably have quick-release capability. The second platform (tripod head) will be the older style, having no quick-release capability. The camera "table" of the tripod head is fitted with a 3/8″ 16 (threads) bolt that screws directly into the camera base. Sliding baseplates, risers, iris rod mounts, and female sliding dovetail plates will have been removed in preparing the hand-held camera. The second head can be equipped with a quick-release system, but this is inefficient.

This requires two additional steps: (1) fixing the sliding baseplate (male dovetail) to the bottom of the hand-held camera before it can be placed on the second (hand-held) tripod, and (2) removing the plate before the shoulder brace can be mounted on the hand-held camera. Installing or removing the plate requires a screwdriver (extra time). The removal will occur at a time near to when the operator may want the camera quickly. And again, taking the plate off is *not* an instant thing. Basically, a second quick-release system negates the advantage of using two heads.

You'll obviously make do with what you have available, but when ordering gear, ask for one old-style head fitted with a conventional lockdown screw at the camera table. This will be very handy if you're going between studio mode and hand-held mode a lot. If you have only one head, halfway through the rebuild you'll most likely have to pull the camera off the head. Screwing little parts onto a heavy, unbalanced object will find the camera fighting you all the way, as you're bent over, sitting on the floor or on a case. It's no fun and it's a lot slower.

If you're forced into this, try to make as many changes (mode to mode) while the camera still rests on the tripod head. Pull the lens and rods, change the eyepiece, remove the 1000-foot magazine, and install the hand-held 400-foot magazine. Doing a mag change on the floor or in someone's lap is awful! It's worse in the dark. Pull the camera and then remove sliding baseplates, risers, iris rod mounts, and female slid-

ing dovetail plates. Then attach the shoulder brace with right- and left-side pistol grips. Phew! You're ready. And you're sweaty, Freddie.

The charted configuration change (see Figure 3-7) allows for all mode changes except the last one (shoulder brace) to be done before the camera is removed from the second (hand-held) head. Working with an object solidly fixed in space is many times easier than fighting an unstable dead weight that becomes very "live" as you fight with it on the floor or even on a table.

At the beginning of the change from studio mode to hand-held mode, the fully built studio camera rests on one tripod head. I leave the right hand pistol grip on the studio camera. It's one more handle. It's one more way to power the camera, and it eliminates a step.

Studio to hand-held conversion sequence: Send the second for the necessary cases. He'll bring two at a time, prioritized by tear-down and building sequence. The order of cases will be zoom case, prime case, mag cases (1000-foot and 400-foot), filter case, and hand-held accessory case (HH-AKS).

This accessory case usually includes hand grips (right and left), shoulder brace, short eyepiece or caps for long eyepiece, hand-held door, hand-held follow focus, small matte box (4×4), or clamp-on hand-held matte box, or clamp-on ring, sunshade, and retaining rings.

As the 2nd gets the cases, the 1st unplugs the zoom cables and "safes" them in his bag. He then pulls the matte box and "safes" that. The 2nd returns with the zoom and prime cases and opens the zoom case only. The 1st removes the extension eyepiece leveling rod and gives it to the 2nd, who also takes away the matte box. The 1st fixes the short eyepiece to the camera. The 2nd retrieves the mag cases (1000′ and 400′). The 1st disengages the focus gear from the lens and unscrews the support bridge.

The 2nd retrieves filter case and HH-AKS case. The 1st removes the zoom lens and "safes" it in its case. He caps the camera and slides it to its new balance point. The 1st removes the long iris rods with follow focus and support bridge still attached. The 2nd "safes" them. The 1st runs in 10 feet of film. The 2nd unplugs power cables. The 1st removes the 1000-foot magazine. The 2nd proffers the body cap. The 1st inserts the body cap. The 2nd stows the 1000-foot mag.

The camera is now in its smallest, simplest, and lightest state. The 1st slides the camera off the sliding baseplate (male dovetail) and, rotating the body around its lengthwise axis, presents the female sliding dovetail plate, fixed to the bottom of the camera, to the 2nd. The 2nd removes the female dovetail. The 2nd "safes" this and opens the prime case. He readies the selected prime (preset). The 1st mounts the camera

Studio to Hand-held Conversion
Arriflex System

Camera is on first of two platforms. The first can be a geared head or a fluid head, both with quick-release capability. The second platform is most often a fluid head. It should have no quick release, but instead be set up with a conventional base with lockdown screw configuration. Right-side pistol grip is already on the camera.

2nd brings two cases (prime and zoom)

1st unplugs zoom cable ("safes" it)
1st removes matte box

2nd opens cases

1st removes long eyepiece

2nd retrieves two more cases (1000′ and 400′ mag)

1st swings away focus gear
1st unscrews support bridge

2nd opens cases

1st removes zoom lens

2nd "safes" it
2nd retrieves two more cases (filters and HH-AKS)

1st slides body to new balance point
1st removes long rods with support bridge and follow focus attached
1st runs in 10′ (film)
1st removes 1000′ mag

2nd inserts body cap

1st removes camera from head

2nd removes female dovetail

1st mounts camera on hand-held tripod (lock-down screw)

2nd proffers prime (preset)

1st mounts prime

Camera is ready for "look see." If none, continue.

1st removes body cap

2nd proffers 400′ mag

1st mounts 400′ mag

2nd plugs in power cables

1st runs in 10′ (film)

2nd readies appropriate matte box or shade and retaining rings

1st mounts same
1st confirms or changes filters

2nd prepares overhang support rod and follow focus

Camera is now ready to shoot

2nd proffers follow focus

1st mounts overhang support rod and follow focus

2nd unscrews camera from tripod and presents camera base to 1st

1st attaches shoulder brace

Camera is now fully ready

Safe to Stow

1st/camera standby

2nd stows "safed" components
2nd removes cases (prime case kept nearby)

Figure 3-7. Studio to hand-held conversion.

body directly onto the camera table of the second camera platform with its lockdown screw. The 1st mounts the prime lens and checks preset.

Though completely "bare-bones," the camera is now ready for "look see." If none is desired, continue. Begin assembling the hand-held camera.

The 2nd prepares a 400-foot mag. The 1st removes the body cap. The 2nd proffers the mag. The 1st mounts it. The 2nd plugs in power cables. The 1st runs in 10 feet of film. The 2nd readies the appropriate matte box or shade/filter system. The 1st mounts that setup. Filters are confirmed or changed. They are set up by the 1st or 2nd.

Still less than fully built for hand-held, the camera is now minimally "ready to shoot." Remember, I always leave a right-side pistol grip on it. So while it is not optimally set up, it is ready if the AD or director says, "We've got to go right now!" If this does not occur, continue. The 2nd prepares the hand-held follow focus. He prepares the hand-held shoulder brace, positioning the left-side pistol grip to an approximation. The 1st mounts the follow focus, unscrews the camera from the tripod head, and presents the base of the camera to the 2nd, who mounts the hand-held shoulder brace. The camera is now fully built and completely ready for hand held operation. If shooting is not immediate, the camera is most safely kept screwed onto and resting on the hand-held tripod head. If shooting may occur "at any time," the camera is best kept idling in its fully built hand-held state with brace attached. "Full ready" with assistant and camera "standing by," the camera is available for immediate shooting. The 2nd finishes transferring gear from safe to stow.

He removes cases.

Hand-held Mode to Studio Mode

Changing the camera configuration from hand-held mode to studio mode is to be done as quickly as possible (see Figure 3-8). However, it seems often there is less urgency at this juncture in the shooting schedule. In going to hand-held, the operator is usually eager to get the camera on his shoulder, to get the "feel" of it. And everybody else seems in a hurry to start experimenting. But now we'll change the camera from its hand-held mode, back to its studio mode. The camera will end up back on its first camera platform: the studio tripod head.

Send the 2nd for two cases according to the tear-down/build sequence (filters and HH-AKS). The 1st unscrews the shoulder brace from the bottom of the camera and "safes" it until the 2nd returns. The camera is screwed directly onto the hand-held tripod head and secured with the lockdown screw. The 1st removes shade or matte box. The 2nd "safes" or stows them. Fragile filters may be removed back to their fil-

Hand-held to Studio Conversion
Arriflex System

1st removes shoulder brace ("safes" it)	
	2nd retrieves two cases (HH-AKS and filters)
1st secures camera base onto lockdown screw of second (hand-held) camera platform	
	2nd "safes" or stows brace
1st removes matte box or shade and filter rings	
	2nd "safes" or stows them 2nd retrieves two cases (400′ and 1000′ mag)
1st detaches hand-held follow focus and rod	
	2nd "safes" or stows same
1st runs in 10′ (film)	
	2nd unplugs power cables 2nd prepares body cap
1st removes 400′ mag	
	2nd inserts body cap 2nd retrieves two cases (prime and zoom)
1st removes prime lens	
	2nd proffers port cap
1st inserts port cap	
	2nd "safes" or stows prime 2nd prepares female sliding dovetail plate
1st removes camera from tripod	
	2nd mounts female dovetail
1st slides camera onto male dovetail/sliding base-plate (premounted on studio tripod head)	
	2nd proffers long iris rods
1st inserts rods	
	2nd proffers support bridge and studio follow focus
1st mounts same	
	2nd prepares zoom lens (dirt check/clean)
1st mounts zoom lens (preset) 1st engages focus gear 1st slides camera to balance point	
Camera is now ready for a "look see"	
1st removes body cap	
	2nd proffers 1000′ mag
1st mounts mag	
	2nd plugs in power cables
1st rebalances camera	
	2nd stows body cap
1st runs in 10′ (film)	
	2nd prepares and proffers matte box
1st mounts matte box	
	2nd plugs in zoom cables
1st fine focuses	
Safe to Stow	
	2nd stows "safed" gear 2nd removes cases

Figure 3-8. Hand-held to studio conversion.

ter case. There is no really safe way to "safe" them. The 1st may do this as the 2nd retrieves two more cases (400′ and 1000′ mag), or, if really pressed, he may continue tearing down and "safing" gear. The 1st detaches the hand-held follow focus and overhang support rod. The 1st runs in 10 feet of film. The 2nd prepares the body cap. The 1st removes the 400′ mag. The 2nd inserts the body cap and unplugs the power cables from the camera. The 1st stows the 400′ mag. The 2nd retrieves two more cases (prime and zoom). The 1st removes the prime lens. The 2nd gives port cap to 1st. The 2nd "safes" or stows the lens. The 2nd prepares the female sliding dovetail plate. The 1st removes the camera from the "hand-held" tripod and presents the camera base to the 2nd. He attaches the female sliding dovetail plate. The 1st slides the camera onto the male sliding dovetail plate, which is mounted on the first camera platform. This is the studio tripod head. The 2nd proffers the long support rods. The 1st inserts them. The 2nd prepares the support bridge and studio follow focus. The 1st mounts both pieces. The 2nd prepares the zoom lens (dirt check/clean). The 1st mounts the zoom lens and engages focus gear. He presets the lens (aperture open, rough focal length, rough focus). If there is no clue to the focal length, it is set at its shortest setting. The 2nd prepares the 1000′ mag (winds out loop). The 1st slides camera to its new balance point. The camera, though not fully built, is ready for a "look see." If none is desired, continue. The 1st removes the body cap. The 2nd proffers the 1000′ mag. The 1st mounts it. The 2nd plugs the power cables into the camera. The 1st runs in 10 feet of film. The 2nd prepares the matte box. The 1st rebalances the camera. The 2nd proffers the matte box. The 1st mounts it. The 2nd plugs in the zoom control. The 1st confirms filters. The 2nd begins safe to stow. The 1st fine focuses at first opportunity. Any filter changes are made by 1st or 2nd. Cases are removed from the camera. Camera balance is checked once more. The camera is now fully built, operational and studio ready, and standing by.

The above descriptions are the major configuration changes a camera may go through in the course of any shooting day. Smaller variations of these changes are more common. A lens change is one example; a mag change is another. A lens change is to be accomplished with expedience; some time will be devoted to lens choice, given creative and technical parameters. A mag change involves no creative discussion. When no more film remains on the feed side, the call to reload is not a matter of choice. The critical issue in reloading is speed.

The Best Reload

In most studio work, depending on the situation, a reload is to be performed relatively quickly. A formal reload may still take a few min-

utes. But, in the studio or in the field, under the gun, a guerrilla reload can be executed in under 10 seconds! This is the most extreme, and the camera type for which this is possible is limited.

The most thorough reload is not usually the fastest reload. The fastest reload is not usually the most thorough reload. Neither one is the best reload. The best reload lies somewhere in between both ends of the spectrum. Actually, the best reload is that most appropriate to the needs of the immediate shoot milieu. It encompasses elements of the most thorough and the fastest reload. We'll explore a few reload sequences from the most thorough reload, to the fastest reload, with and without a 2nd assistant. Into each we will build a preferred task performance sequence. This will optimize precision and speed.

A camera reload occurs when the 1st judges the remaining unexposed footage to be inadequate for another take and possibly a safe length of tail. This ranges from 10 to 20 feet of film. Suppose everyone (talent, director, crew) is on a roll and there's enough film left for a take but no tail. Advise the DP and director. They'll make the call. Or, it might be a borderline case of not even having enough film to complete the take. Let this be known. Indicate the possibility of a rollout. The big dogs will make the call to shoot or reload. When the 1st knows for sure there is only enough film for one more take, he announces at the time the camera is rolled, "Reload after this take." Here is the reload sequence charted out. See Figure 3-9.

The 1st announces a reload based on film supply. The 2nd prepares the next magazine to be placed on the camera. According to the design of that mag, the loop is wound out from a geared mag or just extended from a nongeared mag. In either case the freshly formed loop is optimally shaped for insertion into the movement. The last take on the old mag is completed. The 1st announces the reload. He covers the lens and winds in 10 feet of film. The 2nd prepares a light and air for checking and cleaning the "gate" (aperture plate) and camera interior. The 1st removes the exposed mag and gives it to the 2nd.

The 1st checks the gate. Actual removal of the aperture plate is optional. Removal does provide the best examination of the gate. However, during removal debris may become dislodged and go undetected. Plate removal to clean is optimal.

The 2nd prepares the fresh mag and holds it ready to give to the 1st, who mounts it, sets the loop, checks the run, closes the door, resets the footage counter, and runs in 10 feet of film. He announces, "Camera's reloaded."

Sometimes a short end is loaded into the camera. The 2nd will place a piece of tape near the counter, warning of this. The camera is rebalanced. Beware. This could possibly affect critical focus marks.

There are three basic variations to the above described scenario. One is that the 2nd performs the entire reload. In the second variation, the 1st removes the exposed magazine, checks the gate, and cleans the camera interior. The 2nd attaches the fresh magazine. This variation is slightly faster and safer, because there is one less trading of hands for the magazine. It eliminates a step (or overlaps it) and it avoids a potential risk point, by avoiding the handoff. The third variation is an extension of the second variation. The 2nd removes and stows the exposed magazine. The 1st checks and cleans. The 2nd attaches the new mag. This is the fastest and safest sequence. Tasks are maximally overlapped. The 1st and 2nd remain out of each other's way. There is no time-consuming fumbling and trading of mags and cleaning tools. Most important, the risk point of handing off the precious exposed stock is avoided, as well as the risk of dropping the new mag full of raw stock. (When light, not transmitted by a lens, strikes film an amazing photosensitive reaction occurs. Producers turn a phenomenal shade of bright red.)

No gate check? Could this ever be an option? The studio scenario is a classic, full-dress production setting. It is the most formal and the most thorough. Time is usually available and taken for all layers of production task performance. There are times, though, when the gate will not be checked (Gasp!). If a one-time shot opportunity is occurring, mag change time is minimized by eliminating this step. Filming time is maximized. A clean gate is worthless if you didn't get the shot. The gate will be checked only after the event has passed. But it's still kind of academic, except the integrity of the next take is ensured to a certain degree. The likelihood of this contingency is more germane to documentary field shooting. It is rarely seen in a studio situation.

There is a second set of circumstances in which the gate will not be checked: a magazine reload that occurs before any "printed" takes have been shot and momentum is judged to be important. Try to blow out the gate and film chamber as you change magazines. Also, opportunistic prechecks of the gate during camera stops help increase probability the gate was clean at the time the "keeper" take was filmed.

Speed Work without a 2nd Assistant

On smaller shoots, you may find yourself still in a studio. You still have a need for speed, but you don't have a 2nd. The 1st performs the entire reload. There is no one to overlap consecutive operations or to perform tasks concurrently with you. The answer is: if you can't overlap tasks, you can still overlap time.

Overlap or dovetail the time performing a reload with shooting

Studio Reload
Arriflex System

1st judges inadequate film supply
1st announces final take and upcoming reload

2nd preps new mag (loop set)

Final take is completed

1st announces, "Camera reload"
1st winds in 10′ (film)

2nd readies light and air

1st removes exposed mag

2nd takes mag and proffers light and air

1st checks gate/cleans

2nd proffers new mag

1st mounts new mag
1st resets footage counter
1st check run
1st runs in 10′ (film)
1st announces, "Camera's reloaded"

Contingency for Short End load

2nd displays short end footage label by counter

1st rebalances camera

VARIATIONS: CAMERA RELOAD

Variation #1:

2nd performs entire reload

Variation #2:
1st removes exposed film
1st checks/cleans gate

2nd mounts unexposed mag

Variation #3

2nd removes exposed mag

1st checks/cleans gate

2nd mounts unexposed mag

No Gate Check (two situations)
#1: One-time shot opportunity (rare in studio)
#2: No printed takes prior to reload; momentum is important (camera interior blown out if time) Pre-checks recommended.

Figure 3-9. Studio reload.

time, before and after the reload. When still on the old magazine, you prepare the fresh one. Once on the new mag, you stow the old one. When you approach the last few takes on a mag, open an empty mag case and a fresh mag case. Place them near you or where the dolly move will end. Now or later, steal time to prepare the film loop on the fresh mag. The same sequence reverses itself after the reload.

At the reload, perform all steps: remove the old mag, check/clean gate, mount prelooped mag, shoot. Overlap stowing of old mag, clean-up, and paperwork transitions with the resumption of shooting. This is fast, but there is a faster version of this.

The most "stripped-for-speed" version of this involves one full mag case only. Steal time to remove the fresh mag from its case. Preloop it and lay the mag on any "safe" surface that is next to you. At the reload, remove the exposed mag, lay it at your feet; "safe." Mount the fresh mag-shoot. As shooting resumes, clean up.

This is a drastic technique. It is used when you are sure the situation calls for maximum speed. Make sure the powers that be will not frown on severe guerrilla tactics. The situation and the persons concerned will dictate the degree to which guerrilla tactics may be applied. Chances are they'll love your speed and let you know they're impressed and pleased by it. Be gracious. You deserve it.

What time and speed the above techniques buy you is minimal, but it is better than nothing and it adds up. It is probably never appropriate to trade absolute safety for absolute speed. Again, let the circumstances dictate the degree to which you sell your soul. God bless…

Field: Speed Work without a 2nd Assistant

When you take the show on the road to a location, and it's a big show, you still are basically in a studio environment. But when you go out into the field, hacking your way through the jungle and parting the tall grasses—here you find the documentary and the documentary camera crew. Shhh…don't startle them or they may film you—in an instant. Here you find the true guerrilla. There is no civilization here; no studio, no time, no rules, no money, and no 2nd assistant (and no Perrier). Filming is done very differently out here. We'll look at an entire sports/doc scenario. But first we'll look at the camera reload, out of sequence and up front, just to group it with the general treatment of camera reloading.

This will be almost the most extreme reload, taking as little as 6 seconds. This assumes you have a magazine-threaded camera—an Arri SR, or Aaton. These two are the most widely used cameras in documentary shooting. For an example, let's use a car race where the emphasis is on speed.

As you approach the reload, hold a fresh mag in your hand. Your "hero" car blows by. You announce, " Reload!" If time permits, wind in 5 feet of film. Remove the mag; check the gate. Blow air or wipe the rails (pressure plate) with your finger. Mount the fresh mag, wind in 5 feet of film, and shoot.

The most extreme reload occurs in the most extreme conditions and

usually at the worst time. The crew is shooting and shooting. You notice the subtractive film counter edging toward zero. You say, "We're going to rollout." The director and the DP keep going. They gamble they'll get all of what they want (critical event) before they "tail out." You get a fresh mag in your hand, poised. They shoot to the bitter end (rollout). The big event still has not happened, but its moment is racing ever closer. You snatch the mag off, snap on a new one, and shoot. Elapsed time is 2 to 4 seconds. You get the shot. Bam! You're done. Walk away! Phew! There is no gate check, no cleaning, a safe tail is academic, and winding in a safe head would have happened right over the key event. Now that we've got the shot, let's relax a little and go back to the beginning of our documentary/field shoot.

Equipment Consolidation/Ergonomic Camera Modification

Half the battle is just getting there. A lot of walking and a lot of carrying makes equipment consolidation key. This extends all the way to a special setup of your ditty bag. We are going to choose a race scenario. Sports can be the most extreme form of documentary. Racing can be one of the most extreme forms of sport shooting. The critical event occurs in brief flashes, and the window for these events is constantly closing. Let's go racing.

Small, light, and fast. That's how you "dial in" a race car. That's how you "dial in" a camera. Simple, limited configurations, made of few components that are quick and easy to change, make for the "hot setup."

Here's the basic race package. It's used by Gears Communications, a hallmark in automotive filmmaking. The company has been an integral part of the racing program with Toyota Motorsports Division for nearly a decade. No camera package or shoot is the same. This exposition is exemplary. It conveys important concepts. See Figure 3-10.

Basically, we have one camera, two lenses, 2× telextender, four magazines, four on-board batteries, one block battery, and "sticks" (tripod legs and head). Peripherals are minimal. The entire system can be carried by two people. Gears' crews usually run three to four people, including an optional soundman (sometimes carries). Standard crew is three people: cameraman, assistant, and director (usually carries). This still leaves free hands and backs to carry extra film and changing gear, if needed.

This yields a shooting capability of four lenses and 44 minutes of film shooting time. Potential on-board battery capacity ranges from under 1.5 hours to just under 3 hours. Carrying a 10 amp/hr block battery will add just under 3 hours, running six to eight mags at normal

1 Arri High Speed 16SR (2 power cables)
1 10–100mm Zeiss T2
1 300mm Cannon T2.8
1 2× telextender-Zeiss
4 400′ high-speed magazines
4 on-board batteries
1 10 amp/hr block battery
Medium-duty Ronford lens with riding spreader
Sacthler Video 20-fluid head
Micro Force zoom, cable, motor
Extra control and cable
Filters 40.5: 85 → 85N9
4½ RND: 85 → 85N9
4½ RND optical flat—clear

Figure 3-10. Camera order—basic race package.

speed. This indicates carrying extra film, a lot of it. Off-speed capability extends from 4 to 150 frames/second.

In other words, you can do a lot of different things for a long time, with no base support. Let's run through the camera order.

The camera is an Arriflex 16SR High Speed. The Cinema Electronics (CE) speed control built onto the side is really an add-on. It provides a speed range of 4 to 160 frames/second. A right-side pistol grip adds to the "handle-ability" of the camera. It eases hand-held shooting and provides an extra power switch for the camera. A power cable provides power from block or belt batteries.

Four lenses were mentioned earlier, though only two lenses are listed. The 2× telextender doubles the "specs" of the 10–100mm zoom and 300mm prime. Thus a small optical barrel doubles our "firepower" in more ways than one.

Potential shooting time is dictated by magazine and film supply and batteries. Four full magazines allow continuous shooting time of 44 minutes. Potential on-board battery capacity is 176 minutes (about 3 hrs @ 4 rolls/battery). Privately owned batteries that are completely drained to avoid battery memory can run six rolls apiece. If the small block battery is added to the complement, potential shooting time increases by 66 to 88 minutes, running six to eight rolls. This is a maximum potential shooting capacity of 264 minutes (about 4.5 hours). This much film weighs as much or more than the batteries to expose it. You'll probably never do it. But you can.

Medium-duty Ronford legs and "riding" spreader combine with a Sacthler Video 20 tripod head. This makes a light system that still has

enough "beef" to keep it from twisting and floating through violent operating.

Filters are minimal in sports. Often only a color-correcting Wratten 85 filter is used. Often it is not. The lab can color-correct the film and you gain two-thirds of a stop. If tungsten-balanced film is used, an 85 filter is screwed into the back of the 300mm prime and never changed. The same filter goes on the front of the 10–1 (zoom). Changing to an ND (neutral density) combination takes time and takes away stop. You don't want to do either one. A good stop is important in long-lens, one-chance focus pulling. If either lens is used with the "2x," two stops are lost to begin with. This is bad enough.

Slight and crude modifications are made to certain pieces of equipment in this package. The aim of these small changes is to either reduce long-term fatigue or increase speed.

The first change is to the carrying handle on the camera. It is enlarged roughly three times by being wrapped with camera tape. The tape is much softer than the hard metal handle. This makes 10 to 15 hours of carrying much easier on the hands. More important than softness is the size of the handle in preventing muscle fatigue. The larger handle is gripped differently by the hand. This different grip uses different larger muscles in a different part of the arm. A small fist/finger grip employs smaller, less-powerful forearm muscles. The small grip requires a great deal of constant tensioning. This is very fatiguing. A large whole-hand grip uses the large muscles of the upper arm. These muscles fatigue less easily. They can carry a similar weight while maintaining a more relaxed state. Also, their use allows the smaller, more constantly tensioning, forearm muscles to work much less hard. This alone makes for a fresher crew member toward the end of the day.

The next change is to the tripod head. Speed is increased with some minor sacrifice in safety. On the quick-release lever, the semi-preventative safety lock is removed. Now camera release requires one step, not two. This allows the camera to be instantly snatched from the head for emergency hand-held shooting. There is no fumbling here and no chance of the safety catch sticking, causing loss of the money/story shot. It is often these kind of shots that tell a big part of a sports/documentary story. By themselves they are worth many times that of the more routine shots. The system is many times more powerful and only a little less safe. It still is capable of a "positive lock." Besides, you are professionals. You should be able to handle a slightly hotter, more sensitive, and less forgiving setup than an amateur.

The final change is to the tensioning knob on the clamp-on filter ring. The knob is enlarged roughly two times with camera tape, making it more ergonomically sized. This allows greater torque to be easily applied. This enables the clamp ring to be firmly snugged with one

firm quarter-turn. In reverse, the ring is more easily and quickly loosened. On the off chance that a filter must be changed, elimination of this fumbling point can save up to 10 seconds. Depending on the stadium or road course, you may have a change window of zero seconds up to approximately 01:40 (min, sec). If you're responsible for shooting two cars on a track, you will halve this time allowed. Speed counts.

Everything is aimed at saving energy and time—from the items ordered to how they are modified. This system can do a lot of different things for a long time, and it's fast to use. The above was a discussion of what it can do; now let's look at what to do with it, or how to carry it around.

Carrying: A small camera package is consolidated into fewer carrying cases and bags than is a large one. Fewer cases and bags are easier to carry. Here is how the entire system described above is made to be easy and comfortable to carry, and efficient to use. Again, no two packages are alike, we're talkin' concept.

The camera is most often carried by the operator. It is fitted with the (10–100)/2× lens combination. The tripod is balanced on the assistant's shoulder. The zoom control is mounted in a bracket fitted to the tripod pan handle. A two-hole (purse-style) mag case is carried. Only one hole contains a mag. In the other hole rides the 300mm prime. There is room for the 2× and extra 40.5 filters. (If you don't have 'em they'll want them.) Four on-boards, filters for the 10–100, two mags, and one power cable are carried in one of two knapsacks. This divides the load and shares the effort more evenly. The block battery is carried (it's a case) with a power cable plugged into it. This takes three shoulders and three hands. This means two people can carry everything if push comes to shove. More often, three to four people divide the gear.

Usually the crew makes it back to base before full supplies are exhausted. Often not all mags are carried. The block is carried only when the end of the on-board battery supply is approached. The system carried includes a "built" camera with 2×, two mags, two batteries (redundancy), the 300mm, and tripod. This means one camera, one case, one bag, and one tripod.

No extra film is carried. If everything is carried and you're planning to stay out, film and changing gear are carried in one of the packs. I prefer an extra small zip bag that is strapped to one of the packs. The above is how everything is carried. You say, "There's no mention of a ditty bag. Where is it? Who's carrying it?"

Special ditty bag setup: The ditty bag is carrying magazines and batteries. There is room for this because your ditty bag (classic open-top satchel) has been traded for a knapsack. The design is better for this

kind of work. There's room to carry camera gear because your knapsack carries virtually no tools. It has been almost completely emptied of its normal contents. It is set up to provide maximum room for carrying. Extraneous items are removed to reduce weight and avoid undue fatigue. Again the aim here is to be simple, efficient for carrying and access, and lightweight for energy conservation.

The ditty bag, like car and camera, is specially set up. It is "race prepared." The normal ditty bag weighs about 15 lbs. The specially prepared ditty bag weighs 1.5 lbs. The studio-equipped bag contains about 30 items. See Figure 3-11. The "setup" ditty bag carries about seven items. The studio bag is full and contains everything. The field bag is "empty" and holds almost nothing.

Take your ditty bag and empty it. Or, leave it full and leave it at base. This is where any major surgery would be performed, anyway. In the field you just don't need all those heavy, space-wasting tools.

A knapsack is much better suited for carrying long distances for long periods. A good one, equipped with handles, shoulder straps, and sling strap can be carried at least three different ways. This spreads around the muscle use. Also, its numerous straps and handles can be

Normal Ditty Bag

compressed air
1set jeweler's screw drivers
flashlight
8-ft. metal measuring tape
lens brush
Chamois eyecups
flashlight with magnifying glass
scissors
tweezers
50-ft. cloth measuring tape
Rubber-bulb syringe
two orangewood sticks
set of hex wrenches, 1.0–8.0mm metric (.050"–5/32" BFP [British]) long and short arm lengths
knife
6-in. combination pliers
6-in. needle-nose pliers
depth of field calculator
Sundicator
small rolls cloth tape: 1 black, 1-in.
1 white, 1-in.

superglue
6-in. diagonal cutters
6-in. crescent wrench
1/4-in., 3/16-in., 1/8-in. blade (width) screwdrivers
no. 1, no. 2 Phillips-head screwdrivers
carabiner and/or "S" hook
grease pencils
chalk
large markers: red, green, blue
felt marking pens (small): medium-point
fine-point
rubber bands
lens tissue
plastic cinch straps
lens solution
camera oil
AAA batteries
AA batteries
earplugs

Figure 3-11. Normal ditty bag.

snatched in a fire-drill move much more readily. It can be put down more roughly and because of this more quickly, without spilling its contents. It can be zipped closed against flying mud, dust, dirt, and debris. No open top stares up at a raining sky. The material it is made of is waterproof. The canvas ditty bag isn't.

At minimal weight, providing maximal capacity, a minimum of tools are carried. See Figure 3-12. One can of air; it's a dusty world out there. Carry a very small, almost completely used up roll of white tape. Don't wind some onto a film core. It's quirky, anal, persnickety, at best cute; at worst it is a waste of time. (This practice is for a studio 2nd. They like this kind of thing.) The plastic core weighs more than the cardboard core. The larger-diameter cardboard core is easier to grab from your bag. It is easier to catch, if thrown to you. It can be hung on any protuberance. A film core can't. Remember, harmony with your environment. Bending the world to you is not Zen. The tape should be white. You'll use it for focus marks. White is easier to see in your dark bag. This, too, makes it quicker and easier to grab.

The only adjustments you're ever likely to make to this environment are large, gross changes. So the only tool you're likely to carry is one large straight-bladed screwdriver. You might use it on a snatch-plate or for prying (you heard me), and it's big enough to work as a hammer. (This is guerrilla stuff, pattycakes!) The redundancy is the quarter in your pocket. Only carry one (weight).

A set of jeweler's screwdrivers will probably never be used, but they'll get you everywhere the big one won't. Most often, the kind of adjustments and repairs requiring these fine sizes mean you are probably not into a "quick fix."

Lens tissue: there's really nothing safer for cleaning a lens surface, when combined with air and solution. Weight is negligible. Put some in your pocket.

"Wet Naps" work like lens tissue. And they are infused with alcohol, so you don't have to carry a bottle of solution. They're great for taking dried mud off filters. If you're hesitant about using them directly on a lens, squeeze the alcohol onto some lens tissue or directly onto a lens. They're a great refresher on hot arms and sweaty foreheads. Offer one to the director.

Carry four fine-tip Sharpies, two of one color and two of another. You only use two colors; the other two are replacements. Carry two colors in your pocket. They're fine points, because we're filming fast objects with long lenses. In making focus marks on a lens, the faster the object moves or the longer the lens, the more critical the focus. The thinner the line designating lens focus, the more exact is the mark. The more exact the mark, the more exact the focus point. Decreased focus

tolerance demands decreased mark tolerance. As object focus becomes more critical, lens focus becomes more critical. So do your tools.

$\uparrow$ Object Focus = $\uparrow$ Lens Focus

Carry a small flashlight at night only, to avoid extra weight whenever possible. Most cameras used in pressure/speed documentary settings are "nonthreading." The magazines are "threaded." The mag carries the pressure plate. The loop is set on them, not in the camera. When the mag is removed, the gate and film rails are exposed to daylight. There is no need for a flashlight for peering into dark film chambers.

This is the minimal bag at minimal weight. The handful of tools in it takes up minimum space. This specially set up bag is easier and faster to use. Speed is always a desirable factor. Carrying so very few tools to select from means that each item is more easily located with the eye and more quickly grabbed with the hand. It is lighter and easier to grab and carry. These things all help delay the onset of fatigue. Hey! Minimize to maximize. Zen.

Your other tools and equipment remain available at base, where you can and will return as the situation dictates. If, however, you're going to stay out for extended periods of time, you're going to need extra film and battery power. The specially set up bag aids you to this end in two ways. This bag possesses "add on" capacity, as well as its preexisting extra space, provided by the minimum number of tools that it carries.

Carry film for reloading, as indicated in Figure 3-12. If you're carry-

Ditty Bag Special Setup: Tools
compressed air
white cloth tape: 1/8 roll
1 large screwdriver
1 set jeweler's screwdrivers
lens tissue and solution
4 fine Sharpies: 2 red
2 black
flashlight (night only)

If Carry Film
empty cans = # of (types of) film stock
black tape: 1/2 roll
extra color tape/extra stock
changing bag

Figure 3-12.

ing only one stock, you'll need only one empty can to receive the exposed film. A second can is not needed for a partially shot, unexposed short end. In single-stock documentary shooting, a roll is never partially shot and broken off. If you carry two film stocks, carry two cans. One is for exposed. One is for broken-off unexposed. You may switch stocks in mid-roll if it gets dark. Carry cans of raw stock as per your estimated need. Carry black tape for canning exposed rolls. If you are using two stocks, carry an additional color of tape. This helps distinguish between mags loaded with different stocks. Obviously, it is best if the tape is color keyed to the stocks at hand. And of course carry a changing bag.

The extra film and peripherals can be carried two ways. Both knapsacks will hold mags and batteries. Staying out for an extended time means carrying all your mags and all your on-board batteries. Possibly even the block battery will be taken. The block battery runs so many loads that you might consider dropping some of the on-boards from your pack to regain space and reduce your total carrying weight. Never drop all your on-boards. If your single block dies, you have no redundancy. The on-boards provide greater convenience, speed, and agility to the crew until they are all spent and you resort thankfully to the secure strength of the on-board. (Hopefully, you won't have to shoot that long.) Film cans, tape, and changing bag can be stuffed into the knapsacks around everything else. You can't take a lot of extra film, and with the packs stuffed full, everything is hard to get at.

Strap it on. Add on an extra bag. The knapsacks are made for it. A small canvas zip bag, about 24 inches in length, can be tied by the handles onto any of the numerous straps on a knapsack. This is a good place to mention extra straps. Twenty-four-inch canvas straps looped through a knapsack strap create good add-on carrying capability for your knapsack. Carry at least two. They can safety your extra film zip bag. A changing bag in a stuff-sack is carried neatly by two straps. When strapping on extra bags, snug them to your knapsack as much as possible. If loose, they become swinging weights. This interferes with your balance, causes your body to work harder, and hastens the onset of fatigue.

The ditty bag, like everything else in nature, is just one more example of "less is more." Not every shoot is a documentary, and not every documentary is a race. The above is an example of special modifications for special applications. That is the key point of the whole chapter. Take away the idea, not the exact particulars. The idea is more important because the idea can also be modified for any special application. Develop a system that works for you. On the subject of "less is more" and minimize to maximize, we'll now look at a camera system that works for our race scenario.

Minimal Camera Configuration

The camera is configured in as minimalistic a way as possible, while still allowing it the capabilities to meet the day's shooting requirements. Although a camera is a system made of numerous components, that system is greatly simplified to enhance ease and simplicity of use, as well as speed of operation. Simplifying and minimizing also reduce overall carrying weight, which delays the onset and minimizes the degree of fatigue.

The race-built camera is described like it is built: simply. Spreader, tripod, head, camera, battery, magazine, zoom lens, telextender, filter ring, and shade. The camera has no baseplate assembly, no iris rods, no support bridge, no matte box, and no follow focus. The system has the following modifications: enlarged carrying handle and enlarged filter knob. Filter change time is reduced by roughly 30 percent. The safety catch is removed from the tripod head. This cuts camera dismount time by 50 percent.

The only remaining variables involve the zoom motor and control. You should be ready to remove the zoom motor at a moment's notice. Freeing the zoom movement should take 2 to 3 seconds. Total motor removal should take under 5 seconds. While the motor is in use there is a choice of replacing the pistol grip with an elbow-mounted zoom control. This allows the camera to be snatched from the head instantly. The motorized zoom is available for hand-held shooting and no time is wasted unplugging cables. The downside is that when operating on "stix," the operator must reach awkwardly around the camera to zoom. This almost totally negates a high-speed pan. Also, the position of the hand for operating the zoom is awkward and unnatural. This can contribute to awkward zoom moves. The alternative is the tiller-mounted zoom bracket, or "rock-and-roll" handle. A bracket is mounted on the pan handle and the zoom control is fitted to this bracket. This allows much more loose and natural posturing for the operator. Swish pans are easily performed. Extreme-high-speed pans are never easy, but they are easiest here. The operator is not hugging the camera and in a fast move can get out of the camera's and his own way. The operator's hand is allowed to more naturally interface with the zoom control knob. The benefits are obvious. The more natural position of body and hand helps delay and minimize operator fatigue.

Here is a con. The camera cannot be instantly freed from the head in an emergency, and when it is, motorized zooming is not available to the hand-held operator as the cables have been unplugged to free the camera and the zoom control is still sitting back at the tripod head. Also, the zoom motor makes hand zooming more difficult. Be ready to

pull it! If the operator asks you at this point he won't have much patience, but if you can free it up in 2 seconds you're a hero. Most guerrilla operators will just "muscle" the zoom. A studio guy thrown into the field just might ask. (They whine a lot too.) Just do it for him. Quick!

Here is a trick, used by operators of the tiller-mounted school, to grab unexpected action shots. When not shooting, the camera (sitting on stix) is left "idling" on 10mm. If a crash or something shot-worthy occurs, the operator pans the camera to the shot, at the same time flicking the power switch available at the zoom control. The camera is instantly started as the operator begins to pan. This 10mm zoom setting is wide enough and provides enough depth of field to always render a technically good shot. During the pan, the operator bends to the eyepiece, unlocks the tilt, and reframes the shot. Success rate here is over 90 percent. Director/producers really like guys who do this, for obvious reasons.

GUERRILLA SHOOTING

Here is a "slice" of sports/documentary shooting. We'll describe breaking a setup, making a new setup, and shooting. During the new setup and shooting, we'll describe case layout, getting marks, flying focus (very heuristic), lens changes, mag changes, and battery changes. Let's start at the end. We've got our shot at this location so…

We break the setup. Open cases are closed. The zoom cable is unplugged at the control. This means unplugging only once as opposed to twice. The other two connections are much harder to unplug and each single disconnect takes longer than the zoom disconnect. The operator carries camera and cable. This also makes the new setup quicker. The assistant grabs a knapsack and stix. Learn to automatically balance the legs on your shoulder. They won't fight you and you'll stay fresher longer. The director grabs the other knapsack, if extra, and the purse-style mag case. You may walk. You may run. Don't lag behind. If it's a long move and your body begins to hurt, try to focus on nothing or cultivate enjoyment of the exertion. (We'll talk later about physical exertion.)

You get to the new location. Place the stix where the operator points. As he locks camera onto the head, connect the zoom. You're ready to shoot. Setup time: 8 seconds. Get marks. When able…put down the knapsack nearby. Open the purse case at your feet. In it is one mag and the 300mm. Get the extra knapsack near you when time al-

lows. In it are batteries and more mags. The operator and assistant will have gotten marks by now at the latest.

Getting Marks

Getting marks fast is critical. You'll need to shoot soon, and you may need some practice to warm up to the pull. A lot of focus pulling on moving objects is a kind of brain-learned timing event. This phenomenon figures to a great degree compared to indexing/focusing geographical landmarks. A thin tape strip on the lens does not cover footage scribes on the lens. It can be torn off and replaced with a new one for new marks. There is no fumbling with tape arrows that can fall off. If it gets damp, the strip will last a lot longer than arrows.

Good simple communication streamlines discussion of landmarks. Long descriptions of "Do you see that yellow sign across the track, three signs down from the blue one that…" are confusing and fall victim to parallax error inherent in your two different viewpoints. The problem is that parallax will cause you (two) to establish two (different) object focuses (unwittingly) and one lens focus. Two object focuses dictate two object distances. Simple math says two object distances just won't work with one lens focus. You're discussing sight lines because there are no distinguishing landmarks on plain tarmack. See Figure 3-13. Here you see that two sight lines cross the track at two different points. So the car

PARALLAX ERROR

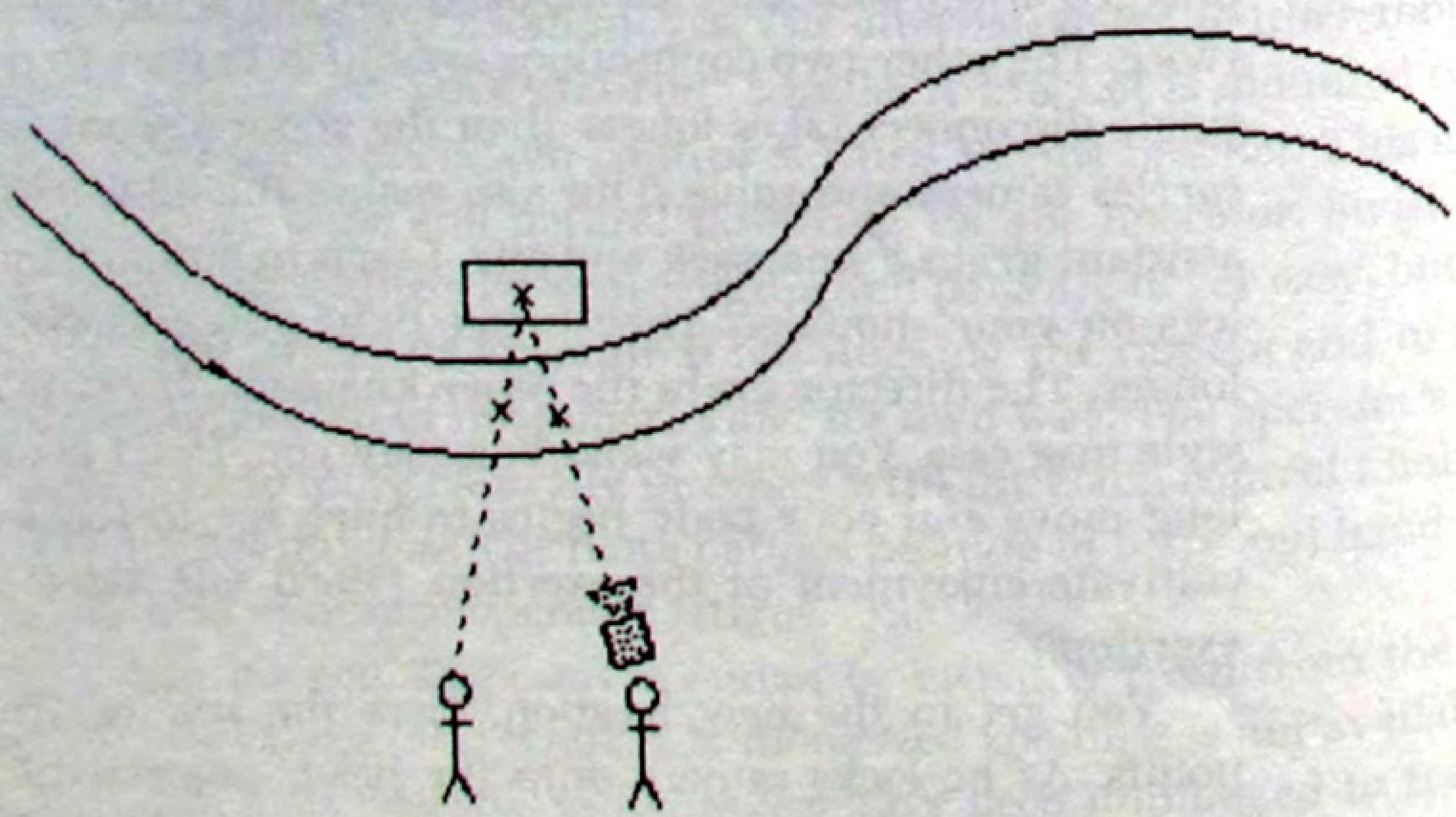


Figure 3-13. In discussing sighting, set a single criterion that all sight lines project along the principal or central axis of the lens.

that the operator's shooting will be on his object focus and lens focus before it is at your object focus. Your different object focus will, of course, have a different lens focus. So in this routine a focus error is automatically built in. You will pull to the lens focus the operator shows you late because you are waiting for the object to arrive at your object focus point.

If you must use sight lines, use only one. That sight line should extend through the camera axis across the track to a landmark. The assumption you both use is that object focus lies approximately halfway across the track, or where both of you have seen the cars establish a "line" (fastest way around a track). Establish and reconfirm this criterion constantly. Sometimes you will need to use this method, but you can see it takes too much confusing description, discussion, and time. There is a faster way.

Focus directly on points on the track. How can you do this? There *are* distinguishing features on blacktop. The car is the distinguishing feature, and it is what you want to focus on, anyway.

This method requires cars on the track. You may sometimes be using the preceding, more descriptive method if you need to get marks early. Then you can practice as soon as cars are out, or you can begin shooting if you don't have much time at that setup. But if cars are already out, use the following faster method. Less talk equals less time.

Speed and efficiency are found in total lack of ambiguity. Discussion and description are minimal. There is no guesswork. The car shows you exactly where to focus, as it moves into the beginning of the shot, through to the end of the shot. Either the operator or the assistant picks the object points that will establish lens focus. As the car moves down the track, one person calls out, "One, two, three, four,..." The operator then sets appropriate lens focus to each point. The assistant marks it with a thin line.

The line should not extend more than halfway across the tape. This is because the shot may include a pan away at receding objects. Object points for these that are equidistant to object points for objects approaching are focused at identical lens focus points (on the lens collar). Mark a thin line with the other color Sharpie on the remaining half-width of tape. The line across from the witness mark for equidistant object points (approaching and receding) will be half black and half red.

Make each line mark a different length. Alternate consecutive lines as long and short marks. See Figure 3-15. This helps the eye greatly in distinguishing one mark from another. This is important because the lines are not distinguished by numbers written on the tape. Writing numbers on the tape takes extra time. More important, numbers (extra

ink) make the tape messier and hard to read. The effect is magnified if you need to make a correction mark. Often the marks on the "long" end of a long lens wind up very close together. As "clean" a tape strip as possible helps avoid confusion.

A correction mark must look different so you can identify it as a correction mark. A correction mark is made of two lines, not one. A correction mark originates at the witness mark, but extends across the tape at an angle. A second line originates at the same point and extends across the tape at an equal but opposite angle. It looks like an arrow. See Figure 3-15. The correction mark takes priority over the original single line mark nearest to it. Do not scratch an old mark. There is no room for the added messiness. If, by chance, a correction mark occurs equidistant between two marks (ambiguous), do not label it as one. Treat it as an additional original mark and denote it with a single line. See Figure 3-16. Now you must eliminate a bogus mark from one side of this additional mark. Scribe a short vertical line, across the bogus mark line, at

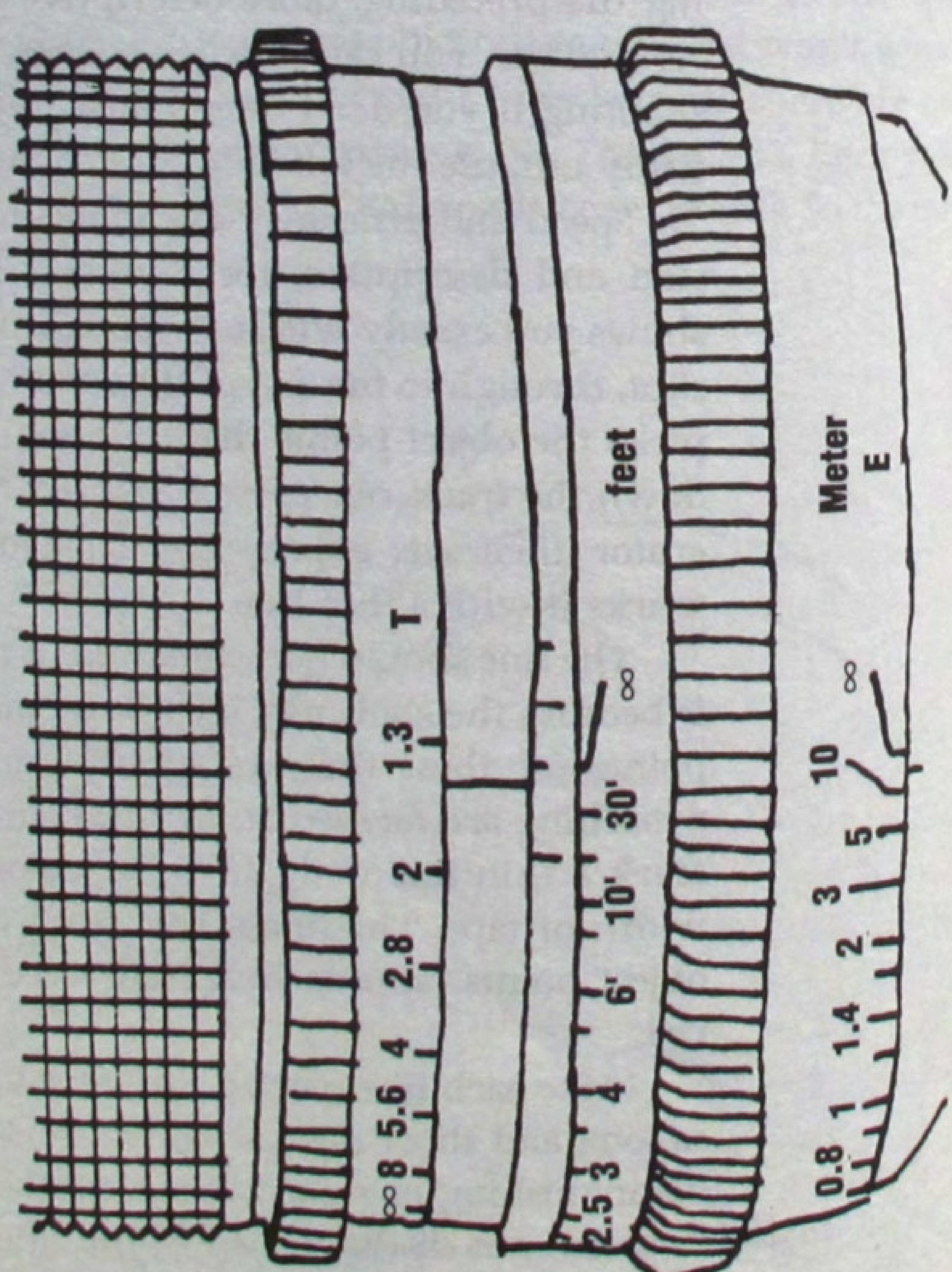


Figure 3-14.
Alternate marks are differentiated as simply as possible by altering mark length.

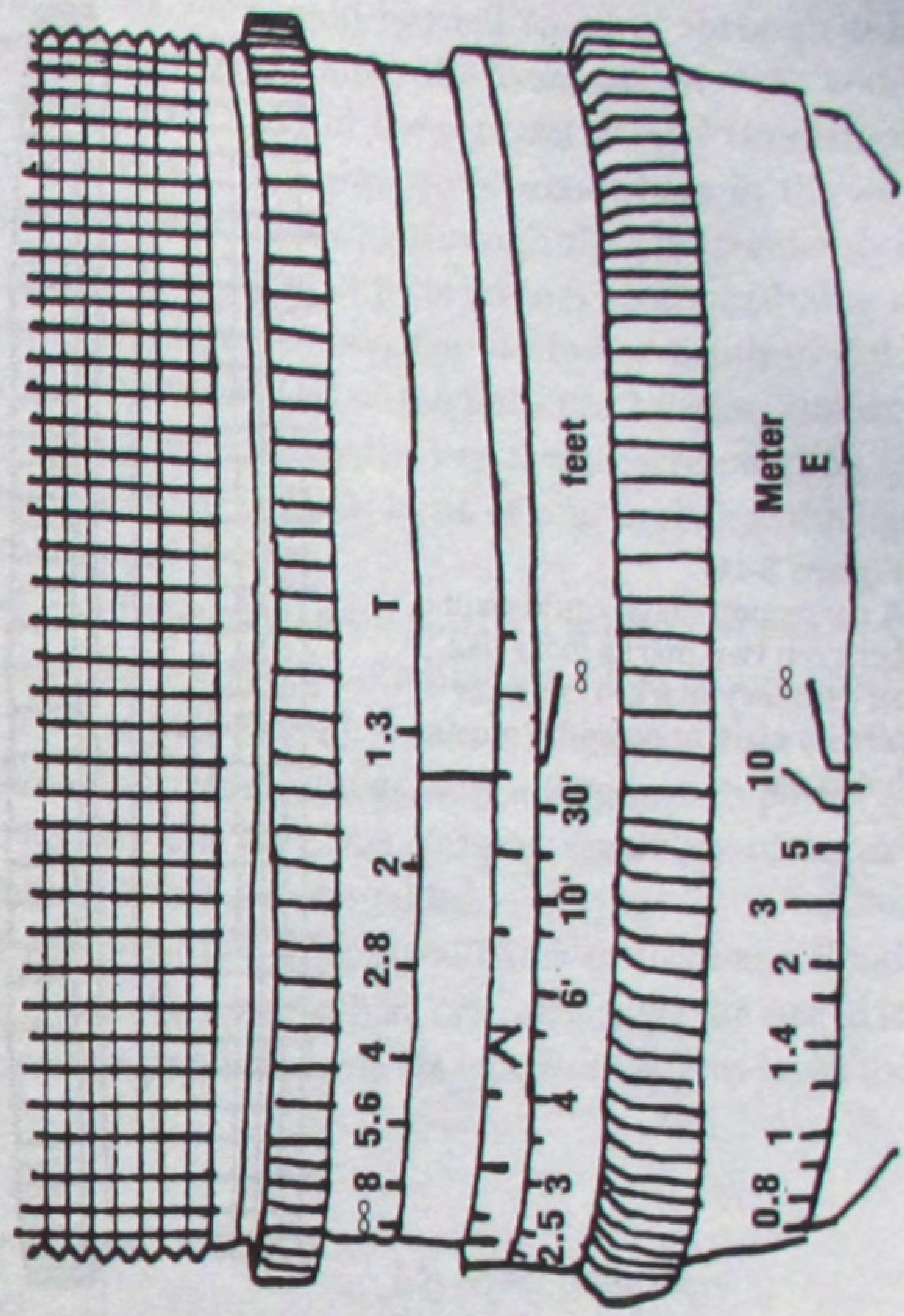


Figure 3-15.
A correction mark (arrow) takes priority over the mark nearest to it.

the end originating at the witness mark. If you must, for clarity, scribe another short vertical line across the middle of the line segment, do not let it touch another line mark. Do not scribe the second vertical line if focus line marks occur very close together. You now have a clean, simple, easily distinguished set of marks.

Priority of Marks

Priority of mark taking can be key to the success of the pull and of the shot. Sometimes conditions preclude not only time to practice but also time to get a complete set of marks. Actually, no set of marks is ever complete. Between two object focus points and two lens focus marks, there exists, in theory, an infinite number of points and marks. In theory, the perfect pull requires lens focus to correspond to object distance perfectly over the entire span of the pull. Experience, and the practical physical limitations of this, show that there is neither time nor need to take every mark for every point. The physical laws of nature make

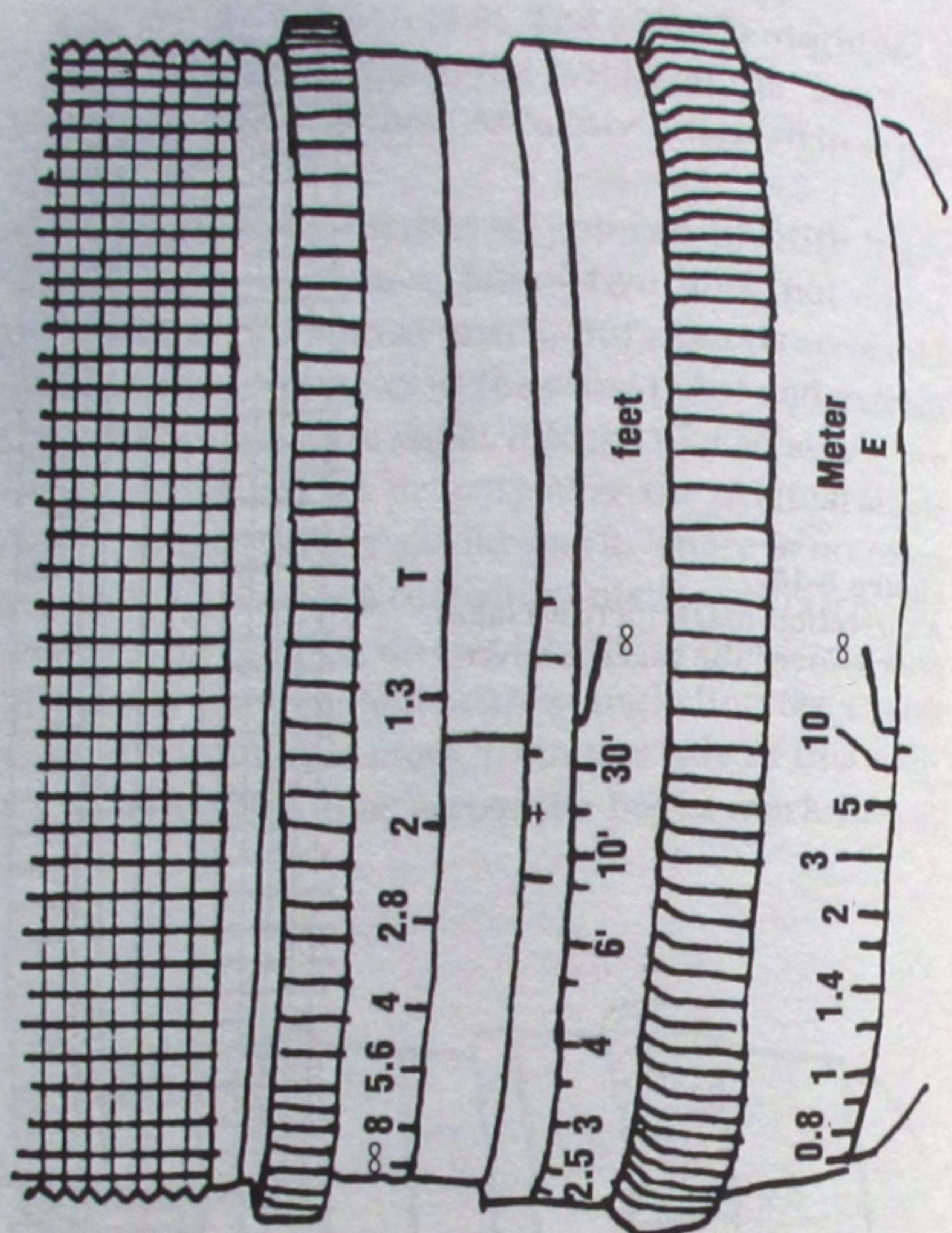


Figure 3-16.
A correction mark equidistant between two marks looks like an ordinary mark. The bogus (error) mark is noted by cross-hatching.

this task literally impossible. To take every mark for every point would literally take forever. Even if one did have infinity to do this, the pull would be almost impossible. The space on the tape between the points at the beginning and end of the pull, containing an infinite number of marks, would appear to be one solid vertical bar the width of the focus tape. The move would become solely a timed event. Your brain just doesn't work on timing chains that long, nor does it learn them that quickly. If you had time, you could eventually learn to make the timed pull. The race would be over though and really your brain would just be dividing the single line into numerous smaller segments and treating those segments like discrete and inexact single focus marks (areas). It would return the solely timed event to a timed/spatial event. Your three or four focus marks do a much faster and better job of this, even though in reality your minimized set is less complete. It is sufficient and adequate. It is heuristic.

But let's go back to the single solid vertical mark made of an infi-

nite number of marks. As your brain learned to move through this pull, at a certain rate, it would be telling your hand and eye, "We want to be somewhere in this first third of the segment at, and close after, the beginning of the pull. Then we want to be somewhere in the second third of the segment about halfway through the pull (remember focus is not linear)." And so on... What your brain is conceptualizing is an analogy of what you physically want to do to the depth-of-field zones from the beginning to the end of the pull. The location and extent of these zones are determined by the lens focus, corresponding to object distance. Object distance and lens focus, of course, change during the course of the focus pull.

Unless... you're at a hyperfocal setting, which is a special case. It is also rarely possible to use a hyperfocal setting on a lens of any "beef" (focal length) for a focus pull. The physical parameters of this would render a boring shot. Hyperfocal settings deny a long lens its potential to operate at full power. The awesome imaging capability of an extreme long-focal-length lens is never attained.

Let's go back to varying DOF zone sizes. Think of focus as a cloud. You can move this cloud closer or farther. You can change the size of it. You can do both by changing lens focus. As you decrease lens focus the

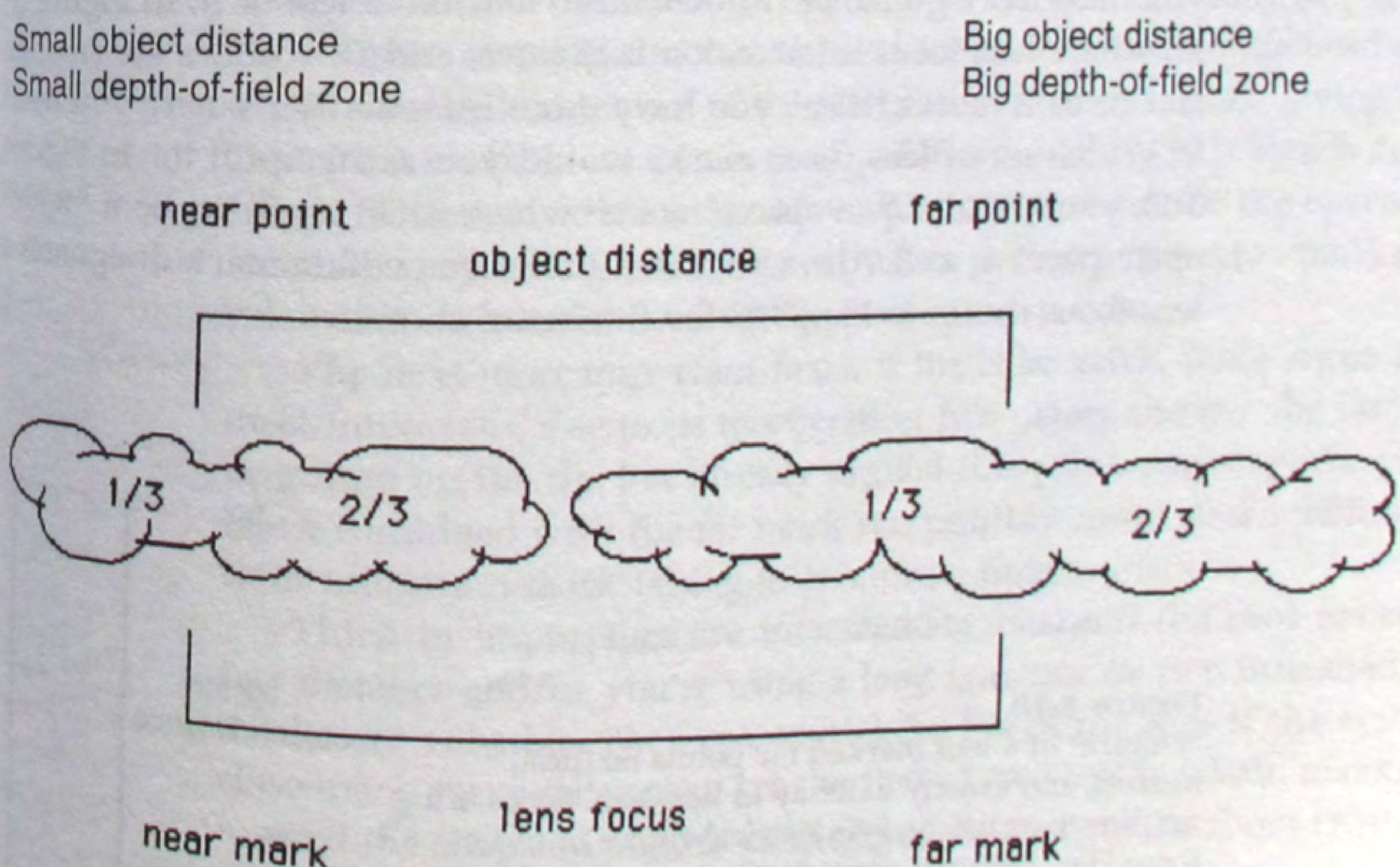


Figure 3-17. Two clouds created by two lens focus marks more than cover focus for an infinite number of object focuses, precluding the need for an infinite number of lens focus marks between near and far marks.

cloud approaches you and becomes smaller. As you increase lens focus the cloud recedes and grows larger. Because of this you may need only a few clouds to cover an entire pull. See Figure 3-17.

This means that only a few marks and their corresponding DOF (depth of field) zone locations and sizes may be adequate to cover an entire pull. A pull with two marks may create two DOF zones that butt up, end to end and cover the entire pull. The same pull with four marks contains intermediate marks and intermediate DOF zones. The intermediate marks are insurance marks and they create overlapping DOF zones.

This is why getting too many marks can really be called overkill. But hey! Insurance is great if you can afford it, but sometimes it just isn't in the cards. Here are the marks to ask for and why.

Ask for the fewest marks that will hopefully cover the entire shot. Ask for the far mark first and the close mark second. If you have time, take an intermediate mark that corresponds to an object point that is less than halfway between the halfway point and the close point. Remember, focus is not linear. A lens mark to focus a far point, a halfway point, and a close point would look like Figure 3-18. A lens marked for points as prescribed would look more like Figure 3-19. In Figure 3-18, notice that lens focus for shorter object distances is a bigger, emptier space. Here, where DOF zones are smallest and focus is more critical, you need more guidance (information) and have less of it. In Figure 3-19, where lens focus information is greater, and DOF zones are smaller and focus is more critical, you have more information where you need it. Which set of lens focus marks would you rather pull to? In Figure 3-19, your "wide-open spaces" occur where DOF tends to be a "wide-open space" as well. Also notice that the intermediate mark designates a lens focus that provides DOF for the entire shot.

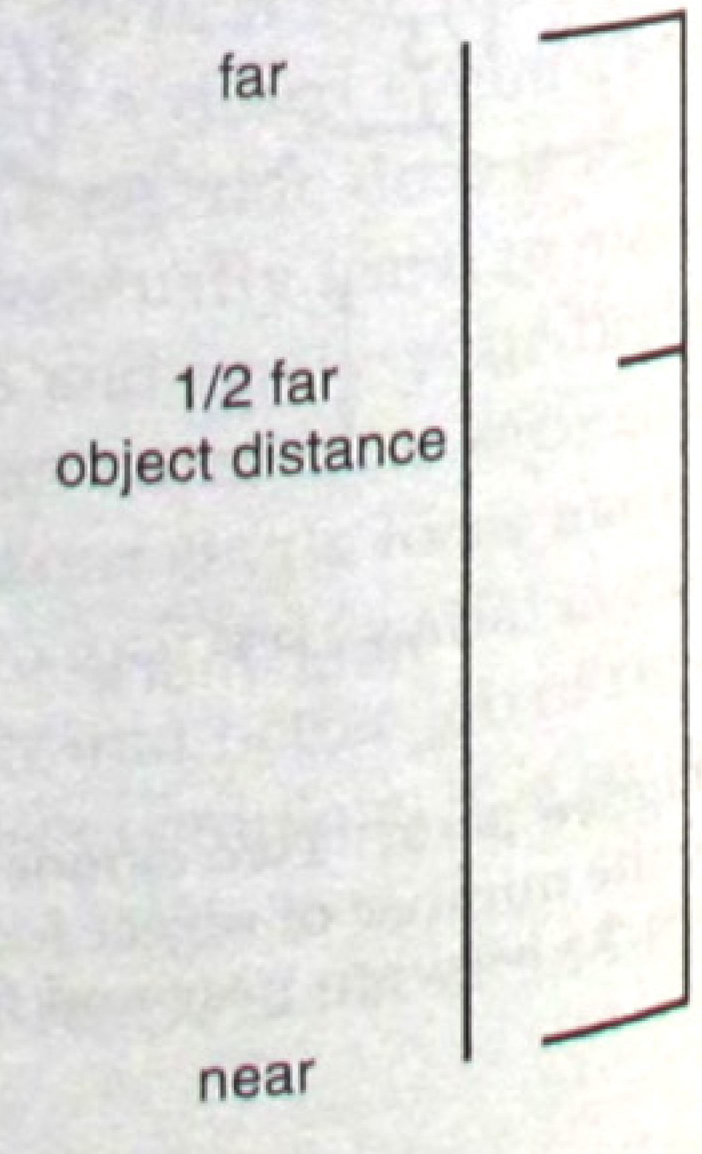


Figure 3-18.
"Picture" of a lens marked for points farthest, nearest, and exactly halfway in between. Focus is a nonlinear property. Symmetrical choice of object focus (far, halfway, close) minimizes marks in most critical zones of focus.

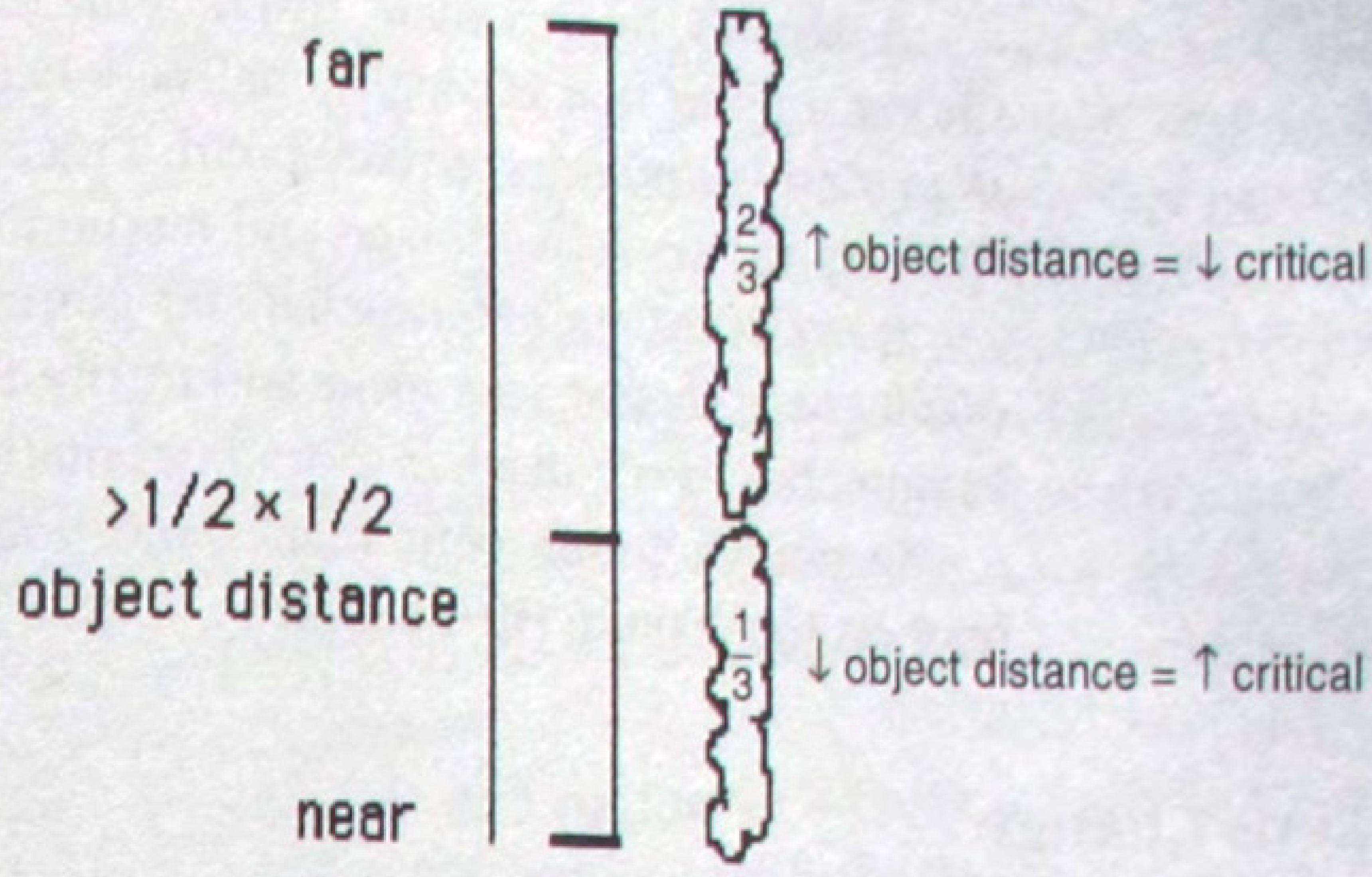


Figure 3-19. Nonsymmetrical (object) focus choices tend to create marks in more critical zones of lens focus.

The far point (object focus) or far mark (lens focus) is your most valuable mark. You get the most for your focusing "dollar." (Laugh here.) At maximum object distance, there is maximum DOF. This single mark will hold focus longest and over the greatest percentage of the shot, compared to any other mark. Also, it is the head end of the shot. If you get no other mark, this mark and a heuristic pull will give the longest piece of the shot. Editors and directors tend to like to cut to the head end of partial shots, as opposed to the tail. Tail ends of partial shots cut in an awkward manner and are seldom used. So the head end is the most valuable part of the shot for two reasons. Also, having the first (far) mark gives you a reset point every time. This avoids fumbling. There is no distraction of readjusting eye focus for the operator. It can be very taxing to his concentration, pre-event focus (mental), and relaxation. Relaxation is a huge part of concentration.

The next most important mark is the close mark. Some argue it is most important, due to its most critical DOF. They also say the far can be gotten on the fly. I've already argued this point. Anyway, the close mark combined with the far mark can possibly cover your whole shot with minimum mark taking in minimum time.

Third in importance are intermediate marks. If the shot covers a fair distance and/or you're using a long lens, one or two intermediate marks are valuable. They can extend the life of the shot if the critical close-mark focus falls apart. Let the first of two intermediate marks be toward the close end. Again, small object distance means short DOF and focus is not linear. You need to fill up those scary wide-open spaces on the focus tape, especially at the closer lens focus values. Pick a point that is less than halfway between the halfway point and the close point. This will help cover you in the more critical, short DOF portion of the shot. Also it will help provide a more evenly spaced set of marks.

A second intermediate mark will, of course, help fill the void. Choose a point that is roughly halfway between the halfway point and your first (near) intermediate point. This mark will fall approximately halfway between the nearest and farthest lens mark on the focus tape.

A midpoint and intermediate far point may be taken. They provide marks near the far lens focus end of the focus tape. They're more of a luxury, but every mark is more information and most welcome.

So you've gotten your marks and you're shooting. You've got the shot on the 200mm (10–100mm/2).

Lens Change

Anticipate the lens change. The director wants to go longer. In our package the next step up is the 300mm prime. The director indicates a "go" to the 300mm. Step square in front of the camera. This is the best position for a lens change. You can see both sides of the camera body and lens. You can see cables to be unplugged. You can see bayonet locks. You can reach B-Mount lens releases. Also, when you remove the lens, it is pulled straight out. This avoids pulling the camera over. Unplug the zoom cable from the motor only. Let it dangle or hang it on the pistol grip. Depress the lens locks. Pull the lens. Lay it down, at an angle (front element up), in the open mag case. If it's raining, put it in your sack with a back cap. Mount the 300mm. Step to the side. This should take about 5 seconds. When you get a small time window, cover the zoom's front element with the 300mm's large front cap. Chances are you pre-marked this lens if you got to your new location without needing to shoot immediately.

Recall is obviously important, when going to a pre-marked lens. This emphasizes the advantage of making a minimal number of marks. It is a longer lens, though, so you may have made more marks for it than for a shorter lens (perhaps only one additional mark). Tell the operator that you're off the 2 and visually confirm his exposure to see if it makes sense. He'll thank you if you catch an error. In firestorm shooting, oversights are easy to miss. Now shoot. If there's film still left. Check the film supply periodically.

Magazine Change

Anticipate a mag change. Pick up a mag from the open mag case. Remove the throat cover. Announce that you're running low so everyone can decide to change in a time window or shoot to a rollout. At the reload, the operator may, because he's standing next to it, remove the spent mag, visually inspect the gate, wipe it and the rails with a finger, and mount the new mag. If he doesn't, you do it. Reset the counter and

run in 5 feet. As you are running in the head, take the spent mag from the operator if he's holding it. At a time window, place it back in its case upside down. If you put it in your knapsack, lay the mag so it is oriented in a way that is distinctly different visually from any other mags containing unexposed film. Resume shooting. The dust has settled. Shooting has resumed. Now is a good time to talk about the gate check.

A gate check at reload with no chance of a retake still has value. A lot of emulsion buildup will alert you to a problem that can usually be traced to a particular mag, which can be retired. It takes almost no extra time as the visual inspection occurs even as the new mag is being moved into mounting position.

There are exceptions to this routine in a faster reload. There is no gate check, only a cursory rail cleaning with the finger, and a new mag is mounted. In the fastest reload, no check or cleaning occurs. The new mag is mounted. Shooting resumes. There is no head roll in or counter reset. This occurs in only the most extreme conditions. But the most extreme conditions can and do occur.

All variations of the above reload scenario can and do occur. All, at their time, are appropriate. Reload time should range from approximately as much as 12 seconds to as little as 4 seconds. This is very fast.

Battery Change

A battery change can be expected after a number of mag changes. A red LED indicates a low battery. The camera will run at speed for a short time longer. Take a battery from your pack, saying in a loud voice, "Battery change."

When the camera is stopped, one of two things will happen. The operator removes the old battery and trades you for the new one. Fast, but there's faster. Step behind the camera. The operator stops the camera. Grasp the old battery, pull it back and up off its pin with a single firm motion of one hand. Mount the new battery. The first change takes 5 to 6 seconds. The second change takes 3 to 4 seconds. Fast!

Nothing is like it is in a textbook—even this one. Your camera may have no external battery indicators. Learn the approximate battery/roll capacity. Change according to this schedule. You near a change point. An important shot is coming up. Change the battery.

Camera Speed Change

The last change is a speed change—ironic. Our director likes to go high-speed on very long lenses. It's a great shot. Cars with their rounded aerodynamic bodies look like giant lumbering marshmallows. They seem to gently bump around off the sides of the frame coming straight

at you. You can see every bit of float, speed wobble, and inertia jiggle at 16 percent motion. "Bumping up" to 150 frames/second is a loss of two and a half stops. The 2× telextender loses another two stops. This total aperture compensation of four and a half stops on a 600mm lens (300mm/2×) becomes very Zen. Remember the force, Luke…

Make the change fast. An Arri SR High Speed has a CE speed control built onto the side. Slide up the safety cover. Adjust the digital setting.

There is a "best" way to do this. It is, of course, the fastest way. And the fastest way is not looking. Having to look and think as you're making a change slows you down. Instead, make the change and then check visually. It's like adding and subtracting in your head, as opposed to counting on your fingers.

This is the method. The speed control "goes out" three places: hundreds, tens, ones. Below and above each denomination is a button. Pushed once, the button raises or lowers the value of the appropriate numeral place by a factor of one. Go from 024 frames/second to 150 frames/second. Push the button below the hundreds place once. Push the button below the tens place three times. Push the button above the ones place four times. Check it. The speed control now reads 150. Raise and lower the respective values of each place using the fewest button pushes. This is the fastest way to change frame rate. Per this example, we have used a minimum 8 button pushes, opposed to a maximum 23 button pushes. The change is three times faster. Visually check the exposure compensation, or announce the new stop and change it yourself. This is something you and the operator will work out.

Flying Focus

Practice is valuable if you have the time. This is a timed/spatial learning event for the brain. You may not be able to practice the actual pull because the director's talking to the operator. You can practice without feedback from the operator. As a car drives through the shot, pull the lens (focus). This will rehearse timing of the move and spatial location of the marks.

Practice of spatial location alone is valuable. Sometimes it happens that, after getting marks, your car is about around again. You won't have time to try a pull on a preceding car. If possible, quickly pull the lens to each mark. You won't learn the timing, but you will rehearse the spatial element, at least once. This helps, because racing focus pulls usually occur very fast, so the pull is partially a blind pull. (See Chapter 2.) Spatial learning will help you hit your marks when you don't necessarily have time to look at each mark and track the race car through the shot at the same time. This is true for studio blocking, as well.

The final eventuality you might face is the zero time setup. There is no time for marks, but follow focus is still needed. An experienced sports operator may try, and succeed, at pulling focus. If the operator's not used to this, he may want you to try. This is flying focus for the heuristic guerrilla assistant. He may "show" you a point or two, setting lens focus on the collar. With no time to put up a new tape strip, you must remember the marks by their distal relations to footage etchings on the focus collar. This ability is also necessary in rain, when dampness makes your focus tape fall off and moisture precludes the use of grease pencils. The focus pull becomes very much a speed/timing event. If the operator tries a follow focus once first, watch the general rate of his pull. This will help give you something to start with. This circumstance does occur. Be ready for it, always, so come the time, your nervousness won't be a complicating factor. Good luck.

So you've gone through the entire slice of documentary shooting. From the examples, you can borrow a foundation on which to tailor your own guerrilla style, given the need. Do everything as well and as carefully as possible. Do everything as fast as necessary and appropriate. A sense of developing speed and precision should be what you take away from this section. Break the setup and move on.

STADIUMS

Stadium shooting occurs regularly in sports photography. Regular is the keyword here. Certain features occur in a regular pattern in stadiums. This symmetry can be used to the focus puller's advantage in distance estimation. In football, soccer, and similar sports, hash marks occur regularly down the field. In football, we know the field is 100 yards long. Each hash mark is 10 yards from the next. In baseball, we know the bases are set 90 feet apart. The baseball diamond can be thought of as two isosceles triangles. They are joined and share a common base or long side.

From trigonometry and our earlier treatment of triangles for short distance finding, we know the following things: an isosceles triangle has two sides of equal length. These two equal sides are perpendicular, such that they are joined at right angles to each other. The hypotenuse of the isosceles triangle is found by multiplying the length of one of the two equal sides by 1.4142 (the square root of 2).

Truck racing in stadiums finds mud tracks built over a sports field. The use of focus arcs finds many focus points with few marks. This promotes speed and accuracy. In any arc, any single mark is good for all points on the same arc. See Figure 3-20. For a typical stadium track,

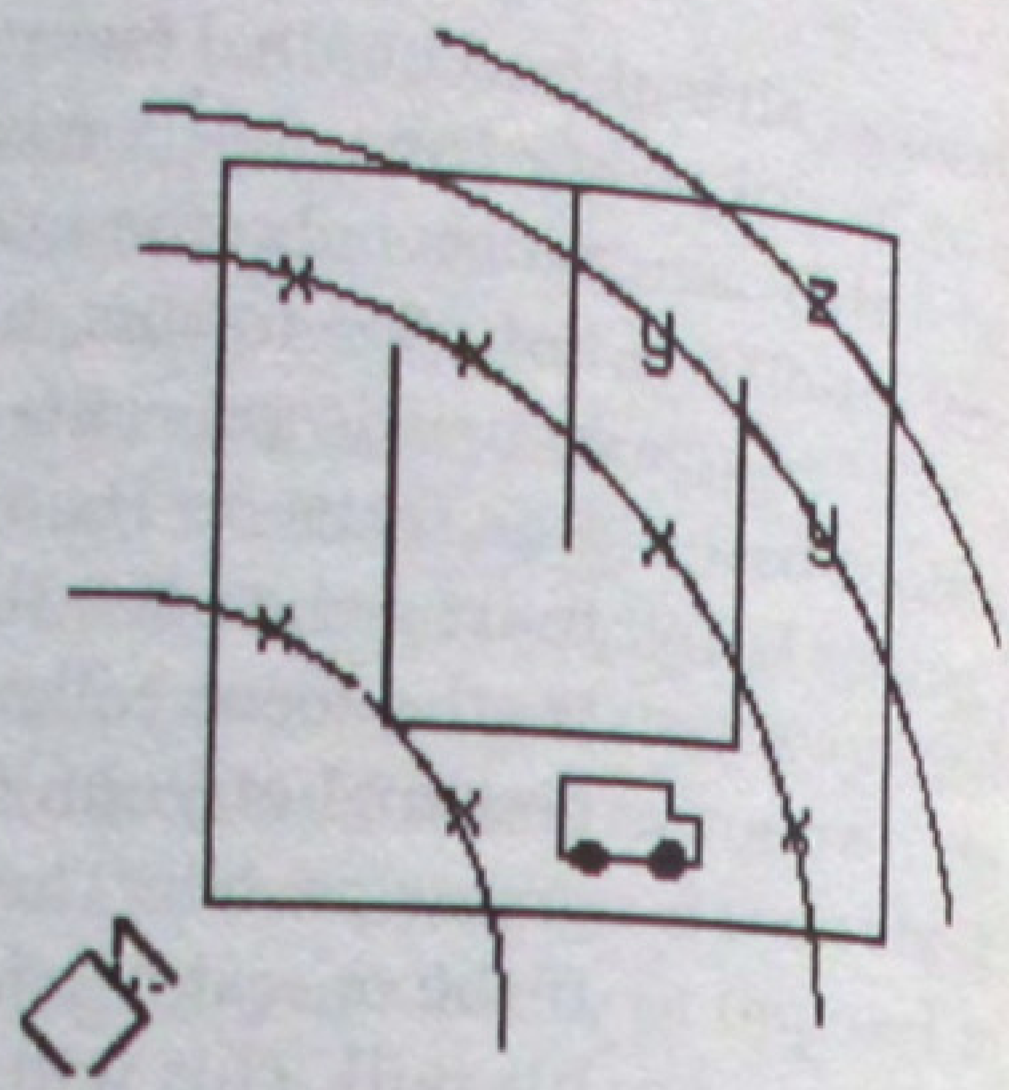


Figure 3-20. Nine critical object focuses covering eight "turns" and eight "straights" are reduced to four lens focus points.

you can cover most of the track with only four marks. Here ten different object points are focused by only four lens points.

The point is to think about and use the environment around you as it applies to your task. You may use some, all, or none of the examples. In my work, I run across these specific focus parameters on a regular basis. I've included them here in this section on field shooting. Take away the theory, and the specific applications will make themselves apparent to you.

DEPTH OF FIELD AND THE LONG-LENS FOCUS PULL

Sports photography in film is very much long-lens photography. This means very much long-lens focus pulling. The long-focal-length lens is what gives power, impact, and kinetics. Here is a brief treatment of the long-lens focus pull in car racing. The lenses discussed are 400mm to 100mm. These lenses can take advantage of the special application of depth of field: hyperfocal distance settings. Lenses of any greater focal length offer minimal DOF, even at fair object distances with "beefy" stops like T8 or T11. On a 600mm lens, focused to 100 feet at a T8, depth of field is less than 12 inches. For these lenses every shot is a special case. The 400mm to 100mm class of lenses can be approached in a generalized manner. This allows an assistant with some prethought and knowledge of the parameters to focus them extremely successfully.

A special application of depth of field is sports photography. Subjects are often at large object distances. This works to your favor. Remember the *lens* focus/object distance rules (multiplication and DOF)

(see in Chapter 4, "Rules of Thumb"). However, to make up for large object distances and yield "big," powerful images, and because sports is shown on tiny TV screens, longer-focal-length lenses are used. This works against you. Remember the focal length rules (multiplication and DOF). The *inverse square law* compares focal length to DOF (see in Chapter 4, "Rules of Thumb"). You may argue that the small screen is more forgiving than the big screen, due to image magnification. While the big screen may show larger out-of-focus images, its larger circle of confusion increases DOF. If you think a small screen and video's accompanying resolution will make focus errors look like anything but mush, you'd better go into advertising, preferably print.

But often in sports you have another factor working in your favor: a good stop (T8 to T16). Many sporting events are outdoors and those indoors are "lit for television." This often means a relatively hefty stop.

Now add to these practical realities a little theory. Let's apply a little of your theoretical understanding of applied depth of field and hyperfocal distance.

In most explanatory situations people start at the beginning, or easiest part. I'm going to begin at the end (story of my life), the far end of focus, or object distance, which is where focus is the longest. I'm also going to start at the far end of focal length. Here focus is the shortest. But if we start here, as we go to wider lenses, everything else will take care of itself.

I want you to have an intuitive, descriptive feel for the qualitative aspects of focus. Rather than sets of numbers designating near and far limits for various combinations of lens parameters (phew), think of this. Visualize focus as a window of depth, or a cloud that grows and recedes as you focus the lens collar away (increase lens focus). The cloud shrinks and approaches you as you focus the lens collar near (decrease lens focus). But once again, to understand the qualitative, we must start with the quantitative.

Let's start with the 400mm lens. This is in a 35mm format (16mm yields greater DOF at all equivalent parameters). So we're starting with conservatively small DOF. Once again, going from hardest to easiest, as does this book. The 400mm is just "wide" enough that, to it, you can apply some general principles of focus to the camera that just fell off the truck.

On the 400mm lens, there is no reasonably usable hyperfocal setting unless you focus the lens at infinity (huge object distance) and set the aperture at T45. Hyperfocal near limits still start at thousands of feet in front of the camera. DPs don't use T45s (diffraction). Engineers use T45s and only missiles are photographed at such large object distances. A lens like the 400mm gets shot most often outdoors at aperture settings

like T11. Let's say the highest numerical etching for lens focus is 200 feet. Set the lens there. At T11, you have a focus window that is over 40 feet deep. If the sun goes behind the clouds, you lose two stops and depth of field is still over 20 feet. Sounds like a lot to you studio guys, doesn't it? Hey! Piece o' cake! A race car goes only about 300 feet/second.

But that's where the Zen part comes in. So let's get gutsy. At 100 feet, the image on the 400mm really starts "poppin'." At your higher aperture settings like T22, you've still got 20 feet of depth. Cut the object distance to 50 feet and you may as well put on a blindfold. And if you're shooting race cars, you've already been run over, or the car's gone past you. Besides, how many operators do you know that can hang a frame on something like that? Well, there are guys out there that are approaching this stuff, and doing it, and with even longer lenses. You be one of them. Let's go to the 300mm.

On the 300mm lens, hyperfocal distance is approximately 375 feet, with the lens focused at infinity and the aperture set at T32. T32 is a stop you'll never use for reasons of diffraction. But if you did and then twisted the lens focus to roughly 375 feet, you would get a hyperfocal window from 185 feet to infinity. Neat! The point is, if push comes to shove, the capability is there. Let's go to some more conventional settings. Set the lens focus at a hard 200 feet. Using more common T-stops of T22, T16, and T11, you've got windows of 170 feet, 110 feet, and 75 feet, respectively. Back to our race car. You know it's halved its distance to you in less than 1/3 second (before you can read this). Set the lens at 100 feet. You can read the guy's helmet! Even at our largest common stop of T11, you've still got 20 feet of depth. A race car isn't 20 feet long, and being a Zen assistant, and having passed "Shapes" in kindergarten, you should be able to put a car's 12-foot length into a 20-foot hole. Let's go to 50 feet. We did it with the 400mm. This should be easier. At Gears Communications for Toyota Motorsports, we do it all the time. Let's go to the 200mm. This lens should make you begin to feel a little more relaxed. Imagine, hyperfocal distance starts at 240 feet, at T22. Set the lens focus to where you think 240 feet is. Focus now starts at 120 feet and goes to infinity. Even at T11, focus is 200 feet deep. You can lose your sun, three stops, and go to a T4, and you've still got 60 feet of depth. The sun's still gone and you're still racing. You pull to 100 feet. At T4, you've still got your good old 20 feet. And again, you're still more apt to be around T11 or T22. The sun goes in and out. So set the lens at 50 feet. You've still got 10 feet. Go to 30 feet. Yeah, you're pushing it with 5 feet of focus. But the shots are just terrific.

Let's put the 100mm on. In sports this is often your shortest lens. Ho hum... Stay awake, now. Remember, you're a professional. Probably the highest numerical etching is 100 feet. Focus to infinity starts at 38

feet. Set it and forget it. Pull the lens collar down to 30 feet, and at T4 we're back to 4 or 5 feet of focus. It depends on whose tables you're using. Doubler anyone?

Sports is commonly shot on a 16mm format. The same lens gives effectively double the focal length while retaining a more forgiving depth of field. The cameras are small, rugged, and light. The 10–100mm zooms are commonly equipped with "doublers," and the 300mm primes are routinely "bumped" to 600mm. This renders an image equivalent to that thrown by a 1200mm lens in 35mm. The 2× telextender makes for a two-stop light loss. In 35mm, lenses from 600mm up to 1000mm are used a lot on car stuff. Telextenders of 1.5× and 2× are common.

The point here is that with a little prethought, a general knowledge of long-lens parameters, and known lighting conditions, there is an area on your lens collar that always yields maximum focus. Set it there. There's the theory. Go practice it.

We have taken our show and put it on the road. We compared shot setup to a theoretical focus sequence. Here, each element of preparation and execution has been examined and included or deleted, according to the shooting environment.

Techniques to improve speed while maintaining precision and safety have been surveyed for use in studio and field, with and without the aid of a second assistant cameraman. This includes equipment consolidation and camera ergonomics.

Guerrilla-style shooting, using all the techniques, has been examined from mark getting to flying focus. A sports scenario serves as a jumping-off point for you to get your own ideas for the particular shooting situations you may find yourself in. Taking marks from regularly occurring features was discussed as it applies to stadium shooting.

Finally the long-lens pull, an example. For an "Extreme Assistant," consistently sharp pulls are your signature, but it carries over.

Consistency is what makes for true excellence. It's not about being great just sometimes, like when the pace is slow and the shooting is "textbook." It never is textbook. The more easily you can adapt to any set of circumstances indicates your true potential performance and value. That's what this whole chapter has been about: adaptability.

4

Infinity Bag

This is a chapter you can get married in—something old, something new, etc. It could be called a medical phenomenon. It looks like an appendix. But it also looks like a chapter. It contains some definitions, formulas, and graphs that are tied to earlier sections in the book. This is for quick reference. It is in this part of the book, rather than at the end, because some of the technical information is anecdotal. I wanted to tie all the technical parts together before going on to more peripheral and general shoot-related topics. This chapter contains a little bit of often argued, but never settled, technical trivia. It outlines one more "in-shoot" technique that doesn't fit anywhere else. It contains instructions for setting up your own medium- to long-range distance estimation model. I hope you get a lot of use out of it. Better yet, what impeccability if you could internalize all that is here. That would make you a really "nasty" assistant. Is "nasty" Zen? It can be.

OPTICS TERMS AND DEFINITIONS

Aberration Monochromatic, five types; chromatic, two types. Aberration is the failure, to varying degrees, of an imaging system to meet any or all three requirements of a perfect lens.

1. All rays emanating from an object point focus at an image point.
2. An orthogonal object plane will be identically imaged as an orthogonal image plane.
3. Object shapes and image shapes are identical. Size is of course relative; subject to given magnification.

Acutance vs Sharpness Acutance refers to the resolution of photographic film. It describes the rendering of a sharp edge in the photographic record. Acutance is tested in an *edge test*, where a "sharp" edge is physically laid against the film. This is not sharpness. Sharpness is a term used to describe rendering characteristics of a lens. An image may have a high resolution (transmitted image) without necessarily having high acutance (recorded image). In reverse, acutance becomes academic. Sharpness is not contrast.

Aerial Image It is a real image before it is projected onto a surface, or as it is being relayed from one visual system to another. It is bright and can be viewed as it exists in space. Natural neuro-perceptual processes (visual accommodation) introduce potential error into any attempt at using this image for focus.

Angle of Incidence The angle to the normal formed by an incident ray (see *rays*).

Azimuth A horizontal location. In navigation, it is designated in degrees and minutes of an arc of the horizon in a specific compass direction of longitude. In optics, it refers to spatial location along a section of horizon.

Breathing Apparent zoomlike effect in a lens as lens focus is changed. This is caused by a minimal change in focal length of the lens. This change is caused by moving the focusing element of the lens backward or forward in the helical mount by twisting the focus collar. This increases or decreases the distance from the center of the lens to the (desired) focal/image point, which changes the focal length and in turn changes the magnification.

Chromatic Aberration (two types) Chromatic aberration can be present without monochromatic aberrations. An example is that a lens corrected for Seidel aberrations in monochromatic light still shows impaired imaging in colored light. There can be interaction between Seidel aberrations and chromatic aberrations.

Sphero-chromatic aberration (SCA) is the presence of chromatic error with spherical aberration. It is the interaction between monochromatic aberration and either of the two types of chromatic aberration. Spherical aberration will determine image heights of colored rays and degree of severity of two types of chromatic aberrations. Zooms show increased SCA with increased focal length.

Longitudinal chromatic aberration (LCA). Image position varies with wavelength. An image changes color longitudinally. A lens disperses collimated white light, forming a primary spectrum giving primary chromatic error. At the focal plane occur multi-

ple circles of confusion. They appear as concentric circles in colors from blue to red.

Transverse chromatic aberration (TCA/lateral color). Focal length varies with wavelength. All wavelengths focus in the same plane, but in any one image plane, different-size color images appear. Another name for TCA is helpful: *chromatic difference of magnification.* Image points appear as spectra radial from the axis. TCA is an oblique and asymmetrical aberration.

Circle of Confusion Object points are imaged by a lens as image circles (or blur patches), not perfect points. This is due to residual aberrational effects. Aberration is never fully correctable. The circle of confusion is a numerical specification of the maximal diametric size of an image circle that still appears as an image point as dictated by format and projection criteria. In 35mm, COC = .025mm, in 16mm, COC = .0125mm.

Circle of Least Confusion Best focus of a point (to its smallest image blur patch) by an astigmatic lens.

Contrast Contrast is related to a lens's freedom from flare. A lens of high contrast will give a greater impression of sharpness than will a lens of lower contrast. But in both cases the image may be equally sharp.

Critical Angle (of Incidence) The minimum angle of incidence at which total internal reflection occurs. This angle is subtended by an arc drawn between the normal and an incident light ray. When the angle of incidence is less than the critical angle, some light is reflected; some is transmitted and refracted (toward the normal).

As the angle of incidence increases, it approaches the critical angle. More light is reflected, some is transmitted, and the angle of refraction (to the normal) increases.

When the angle of incidence equals the critical angle (minimum angle of incidence for total internal reflection to occur), some light is reflected at the boundary (at an angle of 90 degrees to the incident ray). The light that is transmitted is refracted at an angle of 90 degrees (to the normal). This causes the ray to run parallel to the interface surface. This is when total reflection occurs. So…

Critical angle of incidence is the minimum angle of incidence at which the angle of refraction (to the normal) is 90 degrees.

NOTE: Lens coatings change the reflectance/transmission ratio of glass surfaces by altering the angle of incidence. This, of course, alters the relationship of the path of an incident ray to the critical angle. These are the basic mechanics of lens coating function.

Stacking filters can cause halation and degradation of an image, not just by aberration and light vectoring off multiple surfaces. Exposure

of uncoated filter surfaces to each other increases potential reflection and reduces light transmission.

Depth of Focus The distance between the front and rear limits of acceptably sharp image focus. Rays converging to the back-focus limit or rays diverging from the front-focus limit are cones of light. The intersections of these cones are circles. The diameters of these circles are less than or equal to the designated size of the circle of confusion used. A long-focal-length lens has a short depth of field and a long depth of focus. A short-focal-length lens has a long depth of field and a short depth of focus. These mechanics are responsible for the design of the telephoto and retrofocus wide-angle lens.

Entrance Pupil Whatever determines the limit (lens diameter, diaphragm, or image of stop [aperture stop]) to light entering a lens system.

Exit Pupil Determines the limit to light emerging from the lens system. The aperture stop or the image of the aperture stop that is formed by the light after it passes through the lens system.

Focal Length The distance from a lens to a point at which rays from an infinitely distant object (point) will be brought to (critical) focus as an image point (when the lens is focused at infinity). This is usually measured from the center of a simple lens (the optical center of a complex lens).

In a complex lens, this EFL (equivalent focal length) is the net focal length of many elements. It is referred to simply as focal length. As object distance decreases, the focal point (location of focused image) recedes from the center of the lens.

Focus Marks The geographical designation/location of selected object focuses (points); "marks on the floor."

Focus Points The designated points of lens focus for selected object focuses (points); "marks on the lens."

f-Stop A mathematical ratio of focal length to lens diameter (diaphragm, aperture, and/or exit pupil); f-stop = f/d. It describes, as a mathematical analogy, a lens's ability to transmit light according to its dimensions and/or specifications.

Image Focus Rendering of object points (object focus) into acceptably sharp focus as image points at the focal plane.

Infinity (optical) An optical construct. An object is infinitely distant (at infinity) when it is far enough away that the location of its focused image will not change by any measurable amount no matter how much more object distance is increased.

Lens Distance(s) The numerical etching(s) or absence of on the focus collar of the helical lens mount that corresponds to object distance(s). A lens distance can be selected and set in the absence of any corresponding object distance. Example: hyperfocal distance setting. See *lens focus.*

Lens Focus A lens distance setting (etching or absence of) that matches an object distance. When lens distance matches object distance, focus is achieved at the lens, by the lens. This is lens focus. Syn: lens point; lens focus point.

Monochromatic Aberration (five types)

Spherical aberration ($W_{040}r^4$). Marginal rays from an object are brought to closer focus than are paraxial rays. SA is zone dependent. SA is not azimuth dependent or field angle dependent.

Coma ($W_{131}Br^3\cos\theta$). Differential refraction at different zones of the lens, due to changing angles of incidence. Coma is zone dependent and field angle dependent. Coma renders an object point as a triangular image patch of decreasing luminosity.

Astigmatism ($W_{222}B^2r^2\cos^2\theta$). Of orthogonally oriented planes, the meridional (vertical) plane is refracted to a different degree than is the sagittal (horizontal) plane. Off-axis points are imaged as ellipses, circles, or lines, depending on location of the focal plane. A point is imaged as a blur patch (circle of least confusion). The blur patch will change shape and orientation as focus is changed. A cylindrical wavefront, emanating from orthogonally oriented planes, can be taken in a cross section of rays that is circular. The parallel intersection of the plane of this cross section with the focal plane at two different distances from the lens gives two linear image planes that are oriented in two different directions, according to distance of the linear image point from the lens. They are perpendicular to each other; one is vertical, the other horizontal.

Curvature of field ($W_{220}B^2r^2$). More centrally distal points of a flat object plane are imaged closer to the lens. A flat surface is imaged as a paraboloid shape. This effective focal shift for distally located object points gives perfect imagery on a curved surface.

Distortion ($W_{311}B^3r\cos\theta$) (barrel and pincushion). A transverse focal shift giving perfect imaging with varying magnification over the image. This is optical distortion; a true aberration. It is not to be confused with other types of distortion like perspective distortion, geometric distortion, or subject distortion.

Barrel Distortion. A square grid appears to have a convex shape.

Pincushion Distortion. A square grid appears to have a concave shape.

Normal A line segment drawn perpendicular to the plane of a lens surface.

Object Distance The distance of an object in front of the focal plane.

Object Focus The geographical or spatial location of an object to be focused at object distance. Syn: object point; object focus point.

Orthogonal The relationship of planes intersecting each other at 90-degree angles.

Ray A straight line representation of radiant energy flow in the form of waves. Direction of travel is perpendicular to the wavefront. A light ray may be thought of as a line drawn along the path of a photon. A light ray in space (vacuum) is a straight line.

Incident Ray. A light ray before and as it is impinging on a lens surface and is then refracted or reflected.

Chief Ray. A ray that passes through the center of an entrance pupil and lies parallel to the central axis of a lens system. It is the central ray of a bundle of rays.

Marginal Ray. A ray from an object point that passes through the edge of an aperture stop.

Paraxial Ray. A ray that travels close along the central axis, as opposed to marginal rays that are farther off-axis.

Real Image An image that can be projected onto a surface.

Refraction Deviation of speed and angle of travel of a light ray passing from one transparent medium into and through another.

Total Internal Reflection Occurs when a light ray has entered one side of a transparent material (refracting medium) and does not come out the other side. Instead, the light ray travels in a path parallel to the surface and forms an angle of 90 degrees to the normal. Total internal reflection occurs when the angle of incidence is greater than, or equal to, the critical angle of incidence.

T-Stop (transmission stop) A number that is analogous to an f-stop. Its value represents a measurement of the amount of light actually transmitted by a lens.

Vertex The point opposite to and farthest from the base of a geometrical figure.

Virtual Image An image formed inside an optical system. It can be viewed by looking into the forming system. The image can be treated as a virtual object for magnification by other elements in the system. This is how a zoom lens works and why the image does not lose focus throughout the focal range.

Vignetting (physical and optical)

Physical. Light falloff around the edges, or total blockage, of an image caused by physical limitations of the imaging system, aperture stop or image of the aperture stop (entrance or exit pupil), or obstructions in front of the imaging system (matte box, sunshade, etc.).

Optical. Light falloff at the edges of the image due to image magnification (telextenders, macro lenses, etc.).

RULES OF THUMB

Circle of Confusion

Size/Depth of Field A larger circle of confusion means a larger depth of field.

Size/Hyperfocal Distance (HD) A larger circle of confusion means closer hyperfocal distance.

Size/HD Near Focus Limit Doubling the size of the circle of confusion halves the value of the near focus limit for any given hyperfocal setting.

Format

HD (35mm) vs HD (16mm) In 35mm, the hyperfocal distance near focus limit is one-half the value compared to the 16mm hyperfocal distance near focus limit.

DOF (35mm) vs DOF (16mm) At equivalent focal lengths, depth of field in 35mm is almost three times DOF in l6mm. At *proportionally* equivalent focal lengths, depth of field in 16mm is over two times the size of DOF in 35mm.

Focal Length

Multiplication and Hyperfocal Distance The factor by which you multiply the focal length multiplies the value of the hyperfocal distance by the square of that factor.

Multiplication and HD Near Focus Limit (derivative) The factor by which you multiply the focal length multiplies the value of the near focus limit by the square of that factor.

Multiplication and Depth of Field (inverse square law) The *inverse square law* says that depth of field is inversely proportional to

focal length (16mm)	×	factor of 2	=	focal length (35mm)
50mm		× 2	=	× 100 mm
image area (16mm)	(image area)^2	35mm		image area (35mm)
2 units	$(2)^2$ units		=	4 units

I – image area $\quad I_2 = \left(\frac{F_2}{F_1}\right)^2 \times I_1$

Figure 4-1. Image area is related equally to format and focal length.

the square of the focal length. If you multiply focal length by one-half, you multiply DOF by the square of the reciprocal.

Image Area Interaction with Focal Length When focal length is changed, image area is proportional to the square of the ratio of new focal length to old focal length, multiplied by the unit size of the old image area. See Figure 4-1.

Aperture

Aperture Interaction with DOF Depth-of-field interval size is multiplied by the same factor that the value of the T-stop (f-stop) number is multiplied by. If the T-stop number is doubled, the DOF interval size is doubled.

Lens Focus/Object Distance

Multiplication and DOF Depth of field is proportional to the square of the factor by which lens/focus/object distance is multiplied. Doubling the object distance and lens focus multiplies the interval size of DOF by a factor of four.

FORMULAS

I promised a few handy, and some not so handy, formulas, and you'll get them. But first, you will need to look at the Metric Conversion Chart (see Figure 4-2). It's useful for converting millimeters to feet. Modern lenses have their focal lengths described in millimeters, while we think of depth of field in feet. Remember, there are 1,000 millimeters in a meter. See Figure 4-2.

Units of Length

Unit	Inches	Feet	Yards	Rods	Miles	Centimeters	Meters	Millimeters
1 inch	1	0.083	0.028	0.00505	0.000016	2.540	0.0254	25.38
1 foot	12	1	0.333	0.0606	0.000189	30.480	0.3048	304.66
1 yard	36	3	1	0.182	0.000568	91.440	0.9144	914
1 rod	198	16.3	5.5	1	0.00313	502.92	5.0292	50,268,899
1 cm	0.394	0.0328	0.0109	0.00199	0.000006	1	0.01	10
1 m	39.37	3.281	1.094	0.199	0.000621	100	1	1,000
1 mm	.03937	.0032808	.0010936	.000199	.0000006	.11	.001	1

Figure 4-2. Metric conversion chart.

The formulas for hyperfocal distance and depth of field are clumsy, and you'll be best off with a calculator if you should *ever* use them. There are also formulas for speed and brightness. They are intended more to help you internalize the pertinence of lens dimensions and how they relate to light transmission than they are for actual use. Formulas for some of the preceding rules can be found here also.

Hyperfocal Distance

Hyperfocal distance is the critical lens focus distance set on the lens to attain sharp focus, extending from one-half this distance to infinity. It is a special case of depth of field. Depth of field is based on the variable hyperfocal distance. The value of this variable is based on focal length, aperture, and circle of confusion. We tend to think in terms of focus hinging on object distance and its effect on lens focus. This is very much the case with DOF.

Note that the value of this variable (hyperfocal distance) does not take object distance into consideration. The solution to this equation (hyperfocal distance) provides a critical lens distance value. This value, used for lens focus, and set on a lens of given focal length and aperture, yields a maximum range of object distances rendered in sharp focus.

Hyperfocal distance formula

$H = F^2/(f \times d)$

H = hyperfocal distance

F = focal length

f = f/number of relative aperture (use T-stop)

d = circle of confusion diameter

Depth of Field

Depth of field is the range of acceptably sharp focus in front of and beyond a subject, at a specific object distance, for which critical lens focus has been set. This range of focus extends one-third of its length in front of the subject. It extends two-thirds of its length beyond the subject. So the range of acceptably sharp focus is twice as large behind the subject as it is in front of the subject. Depth of field is a function of hyperfocal distance for a particular focal length lens after that lens has been set at a specific lens focus other than infinity. Before lens focus is set, depth of field does not apply. Without a specific critical lens focus, other than infinity, only hyperfocal distance can be discussed. Hyperfocal distance is completely independent of object distance and lens focus. Without a specific critical lens focus, depth of field for any practical purpose does not exist. Depth of field applies only to a lens on which a specific lens focus has been set. Entering this finite distance into the math using object distance values that are less than the value of the hyperfocal distance setting pulls the depth of field forward from infinity and yields a focus range and distance interval of finite length.

Depth of field formula

Near limit = $H \times u/[H - (u - F)] = R$

Far limit = $H \times u/[H + (u - F)] = S$

DOF Interval Size = $T = (T = S - R)$

S = far limit

R = near limit

F = focal length

H = hyperfocal distance

u = lens focus distance

Depth of Field (35mm vs. 16mm): Which Is More Forgiving?

This question has been argued for as long as there has been light. Here, at last, is the answer and why. Well, the answer is: it depends... almost. This is because DOF is a value that depends on the variables of focal length, object distance, and hyperfocal distance, and because hyperfocal distance depends on the variables of focal length, aperture, and circle of confusion. Note the influence of focal length, used twice, and the circle of confusion used in the basic hyperfocal distance equation.

The two variables, focal length and hyperfocal distance, become the weightiest variables in determining the "forgivability" of the two formats and their accompanying depth of field. Depth of field, compared for the two formats (16mm and 35mm), fixes the circle of confusion for

each format. Some (very technically oriented) DPs will fudge the circle of confusion size used in the equations if a nonstandard form of projection will be used for the format they are shooting in. So, after fixing circle of confusion, this leaves focal length as the only remaining variable. But let's look first at the influence and effect of DOF.

A larger circle of confusion means a larger DOF. Let's plug some values into our formulas. We'll start with hyperfocal distance:

$H = F^2/(f \times d)$

H = hyperfocal distance
F = focal length
f = aperture
d = circle of confusion

Let's compare the two formats (16mm vs 35mm). Let's choose a 50mm lens at T4. First, when solving equations, always list your variables.

Format: 16mm (COC = .0125mm)

F = 50mm
f = 4 (T-stop)
d = .0125mm
$H = 50^2\text{mm}/(4 \times .0125) = 50{,}000\text{mm}$

Convert to meters, then British foot/pound system:

(50,000mm/1000) × 3.281 feet = 164.05′
HYPERFOCAL DISTANCE: = 164.05′
NEAR FOCUS LIMIT = 82.025′

Now let's run this hyperfocal distance equation for 35mm.

Format: 35mm (COC = .025mm)

F = 50mm
f = 4 (T-stop)
d = .025mm
H = 502mm/(4 × .025mm) = 25,000mm

Convert to meters, then British foot/pound system:

(25,000mm/1000) × 3.281 feet = 82.025′
HYPERFOCAL DISTANCE = 82.025′
NEAR FOCUS LIMIT = 41.0125′

Remember our rule of thumb that says doubling the circle of confusion halves the near focus limit.

So here, 35mm gives focus that extends to half the distance in front of the focal plane that 16mm gives. So we could say that 35mm is more forgiving than 16mm. Surprised? Well, a lot of DPs grumble, "But have you worked in '35,' kid? Focus is a lot harder. Heh, heh..." (self-satisfied chuckle here). Hey! Piece o' cake!

But there's more to the story. It's tied up in the phrase, "Same image size, same depth of field." This phrase applies "in format." It's used on sets where you obviously aren't switching formats to manipulate image size and depth of field. However, across the two formats, negative size is different and so is proportional image size. This is why circle of confusion is basically fixed by the format. Now what is image size manipulated by? The only remaining variable: focal length. Image size can be changed by changing object distance, but we will leave it for simplicity of argument. Also changing object distance changes composition, and no director's going to stand for it—having you mess with his palette.

So let's plug our hyperfocal distance numbers into the DOF equations. We need an object distance value for "u." Let's choose 50 feet.

Format: 16mm (COC = .0125mm)
F = 50mm (.16405′)
H = 164.05 feet
u = 50 feet
f = 4 (T-stop) NA (does not apply)

Depth of field:
Near limit = H × u/[H + (u − f)]
Far limit = H × u/[H − (u − f)]

Substituting our values:

Format 16mm (COC .0125mm)
(all values converted to British)

Near limit:
164.05′ × 50′/[164.05′ + (50′ − .16405′)] = 38.349877′
38.349877′ = 38′4″ (approx.)

Far limit:
164.05′ × 50′/[164.05′ − (50′ − .16405′)] = 71.816908′
71.816908′ = 71′10″ (approx.)

DOF RANGE: 38′4″ to 71′10″
DOF INTERVAL SIZE: 33′5″

Format 35mm (COC .025mm)
(all values converted to British)
F = 50mm (.16405′)
H = 82.025′
u = 50′
f = 4 (T-stop) NA

Depth of field:
Near limit:
82.025′ × 50′/[82.025′ + (50′ – .16405′)] = 31.102839′
31.102839′ = 31′1″ (approx.)
Far limit:
82.025′ × 50′/[82.025′ – (50′ – .16405′)] = 127.41134′
127.41134′ = 127′5″ (approx.)
DOF RANGE: 31′1″ to 127′5″
INTERVAL SIZE = 96′4″ (T = S – R)

Depth of field in 16mm is 35 percent the size of DOF in 35mm. The interval size in 35mm is 288 percent the size of the DOF interval in 16mm. Depth of field interval size in 16mm is 188 percent larger in 35mm compared to 16mm. So 35mm is more forgiving with a larger depth of field, right? Wrong! Or, at least, not necessarily.

Image size is the key. The proportional relationship of image size to negative size that occurs across the two formats, 35mm and 16mm, is the consideration used in focal length choice. The picture area of 35mm negative is four times that of 16mm negative. To achieve an image size in 35mm that covers a picture area equivalent to that covered in 16mm, a focal length multiplied by a factor of two is chosen.

Remember, image magnification is a "square" relationship. The area covered by a lens twice as long is four times as large. See Figure 4-1.

This means that in 35mm (format), a 100mm lens is chosen to do the job a 50mm lens can do in 16mm (format). Entering this new focal length value into the hyperfocal distance and depth of field formulas changes the numbers achieved dramatically.

Let's compare the DOF for the two formats using focal lengths for each that yield proportionally equivalent image sizes.

We'll use a 100mm lens in 35mm (format) and a 50mm lens in 16mm (format).

Hyperfocal distance
Format: 35mm (COC = .025mm)
F = 100mm
f = 4 (T-stop)
d = .025mm
H = 100^2mm/(4 × .025mm) = 100,000mm
Convert to meters, then British foot/pound system:
(100,000mm/1000) × 3.281 (feet) = 328′1″
HYPERFOCAL DISTANCE = 328.1′1″
NEAR FOCUS LIMIT = 164′½″

Using twice the focal length gives us a near focus limit four times as far away. Focus has gotten smaller. Remember, this is a hyperfocal range from 164′½″ to infinity.

At hyperfocal settings, both interval size and range size are of infinite length. So if focus has gotten smaller, this means it is possible for infinity to come in different sizes. Think about it. Also, see the "Rules of Thumb" derivative for focal length multiplication and HD near focus limit.

Now, given a new hyperfocal distance value, let's run our DOF formula for a 100mm lens in 35mm (format).

Depth of field
Format 35mm (COC = .025mm)
(all values converted to British)
H = 328.1′1″
u = 50′
F = 100mm (.3281′)
Near limit:
328′ × 50′/[328′ + (50′ – .3281′)] = 43.423934′
43.423934′ = 43′s″ (approx.)
Far limit:
328′ × 50′/[328′ – (50′ – .3281′)] = 58.923263′
58.923263′ = 58′11″
DOF RANGE: 43′5″ – 58′11″
DOF INTERVAL SIZE: 15′6″ (T = S – R)

Depth of field (interval size) size in 16mm is now over 215 percent the size of DOF (interval size) in 35mm. The DOF (interval size) in 35mm is 46 percent the size of DOF (interval size) in 16mm. Depth of field (interval size) is 115 percent larger in 16mm than it is in 35mm. My, how things change.

This effect is largely due to the increased value of H in the 16mm

format (at equal focal lengths [50mm]). In 35mm, at an equal focal length, the larger circle of confusion in the denominator makes H a smaller number. H is a ratio of focal length to aperture multiplied by circle of confusion. To this end, note also that if we stop down, which increases the value of f (aperture), the denominator grows larger still. H becomes smaller. The near limit focus value becomes smaller. Review how reduced aperture openings restrict the size of the cone-shaped patterns of light rays and in turn the number of light rays that will pass the exit pupil to go on to form an image. Increasing the aperture value accomplishes this "mathematically" (decreasing the value of H) in the same way that an increased circle of confusion does. The number in the denominator becomes larger, which makes the ratio smaller, which makes H smaller. However, it accomplishes the same end (decreasing H and increasing DOF range and interval size) physically/mechanically, in an opposite or complementary way. A larger COC criterion allows for object points to be imaged as larger blur circles that are still acceptable. A larger f value (smaller aperture) restricts the acceptable admittance angle of rays emanating from an object point. Admissibility of imaging rays to the system and through the exit pupil is limited more closely to those that are traveling at angles that converge and diverge within allowable COC tolerance limits.

When focal length is doubled (35mm format), the value of H (35mm format) is increased. It is quadrupled because we are quadrupling the numerator. Doubling the focal length is what we do in 35mm to achieve equivalent image size. Remember, in the formula for HD focal length is squared. Remember the relationship of image area to focal length. Multiplying focal length squares the image area: $xF = (xI)^2$. Now take H and plug it into the DOF formulas. In the near limit equation, it gives a numerator four times the size: $H \times u = 16{,}400'$ ($H = 328.1'$), compared to $H \times u = 4{,}101.25'$ ($H = 82.025'$) (comparing a 100mm lens to a 50mm lens).

The denominator is increased less drastically, by less than three times. This is because here we are adding and subtracting, not multiplying and squaring. So the larger increase, or stronger effect, is in the numerator. This makes the near limit ratio larger. This effect on the denominator is augmented by F (which is doubled in 35mm) being placed in the denominator, further decreasing the value of the number. This contributes to making the equation even more "top heavy." This makes the near limit solution a larger number, which pushes focus farther away from you.

In the far limit equation, again the numerator is increased four times, by using the new, "beefier" value of H. Due to subtraction, used in the denominator, the effect on the denominator is much greater. The

reversed sign in front of the parentheses decreases the denominator much more here than in the near limit equation. This makes the denominator much smaller. This makes the ratio larger (compared to the near limit value) and yields the greater far limit value (compared to near limit value). H is enough larger here (328.1′ vs 82,025′) that while the numerator is increased four times (16,400′ vs 4,101.25′), the denominator is increased over eight times (278.3′ vs 32.2′), as the strong effect of a large H is combined with the reducing power of the reversed sign in front of the parentheses. This reduces the value of the far limit ratio greatly, which gives a much smaller solution. This pulls the far focus limit toward the film plane. The increased value of F in the denominator here shows no significant supplemental effect.

So at equivalent focal lengths, across the two formats (16mm vs 35mm), depth of field is larger in 35mm (almost three times). At *comparable* focal lengths, across the two formats (16mm vs 35mm), depth of field is larger in 16mm (over two times). The variation is due chiefly to focal length, which determines image magnification.

So now that you know the definitive answer, we'll conclude the section with a bit of trivia.

Q: When does decreased lens focus distance create increased depth of field?

A: When lens distance is decreased from infinity to a hyperfocal setting.

MORE FORMULAS

I'm reintroducing this section because of the need to place the depth-of-field argument near its treatment as a formula and now there is a need to return from that necessary digression to formulas dealing with other lens parameters.

The next formulas show the relationship between the depth of field and a lens's ability to transmit light. Transmission performance varies according to its dimensional ratio of focal length and diameter (of aperture, and/or entrance pupil and/or exit pupil).

Relative brightness and/or speed of a fixed aperture lens is a function of focal length. Brightness is determined as the diameter of a lens (aperture) is divided by the focal length. The reciprocal of the relationship of the two yields whole numbers called f-numbers. These days we use T-stops, a more accurate measure. See T-stops in the section "Optics."

Brightness and Speed of a Lens and DOF

Brightness Formula

Brightness = (diameter of lens)^2/(focal length of lens)^2

Modern lenses contain a variable diaphragm. The aperture this creates acts as an entrance pupil. So...

Brightness = $(d_e)^2/F^2$
d_e = diameter of entrance pupil
F = focal length

The reciprocal of this yields whole-number f-stops. The f-stop represents the speed of a lens. So...

Speed = $1/(d_e)^2/F^2 = F^2/(d_e)^2$ = f-stop

Mechanics of Aperture and DOF

We know that different focal lengths create different depth-of-field ranges and interval sizes. We also know that different aperture settings create different depth-of-field sizes. This is why...

Different-focal-length lenses create different depth-of-field sizes partly because different focal lengths dictate different aperture sizes. The f-stop or T-stop number is a relative value for a relative aperture size (remember the ratio), so the numerical value designation (T8, T4, T2.8, etc.) stays the same. The keyword is relative. The key concept is relative aperture size. Actual aperture size is dictated by the aperture size that is relative to a particular focal length.

Aperture size determines the convergence angles of rays emanating from a point that are admitted to pass through the lens system and on to focus (forming an image) in front, at, or behind the film plane. If the convergence angles are small enough to allow rays to pass through the aperture, the cones of light that the ray bundles form approach sizes that are equal in size to, or smaller than, the designated circle-of-confusion size. This is such that the intersection of the film plane with these cones before (critical focus behind film plane) or after (critical focus in front of the film plane) their focal points creates image circles small enough to appear as points. These image circles are considered acceptably sharp. See Figure 2-1.

Now why do different-focal-length lenses have different aperture sizes that are designated by the same f-stop/T-stop value? This is why:

$$f = F/d_e$$

And this is why:

$$A = \pi r^2$$

Remember that an f-stop number represents a ratio of focal length to aperture diameter. Because of this relationship, a larger focal-length value dictates a larger aperture diameter, to maintain the same ratio. Let's take an example.

If an aperture measures 50mm, and a lens has a focal length of 100mm, what is the speed of this lens?

$$f = 2$$

Because...

$$f = F/d_e = 100/50 = 2$$

On a lens of smaller focal length, the aperture is accordingly smaller to maintain the same relationship. See Figure 4-3.

So...if we decrease focal length to 50mm, what must the diameter be to maintain a relative aperture value of f2?

$$d_e = 25\text{mm}$$

Because...

$50/d_e$ = f2, and $2(d_e) = 50$, and $d_e = 50/2 = 25$mm. And remember a smaller aperture creates greater depth of field, due to its interaction with emanating rays, allowing those with more narrow convergence angles to pass through the system and on to form an image. See Figure 1-4.

Although the apertures in the two examples are each a different actual size, they are both the same relative size. The images they transmit are equally bright. The aperture diameter for the 100mm lens is twice as large because of our second relationship:

$$A = \pi r^2$$

This is the formula for the area of a circle, and a circle describes an aperture. Remember, a lens of twice the focal length projects an image over four times the area, compared to its shorter-focal-length counterpart. See Figure 4-4. So if we let r = the radius of our aperture and use our area formula, we have...

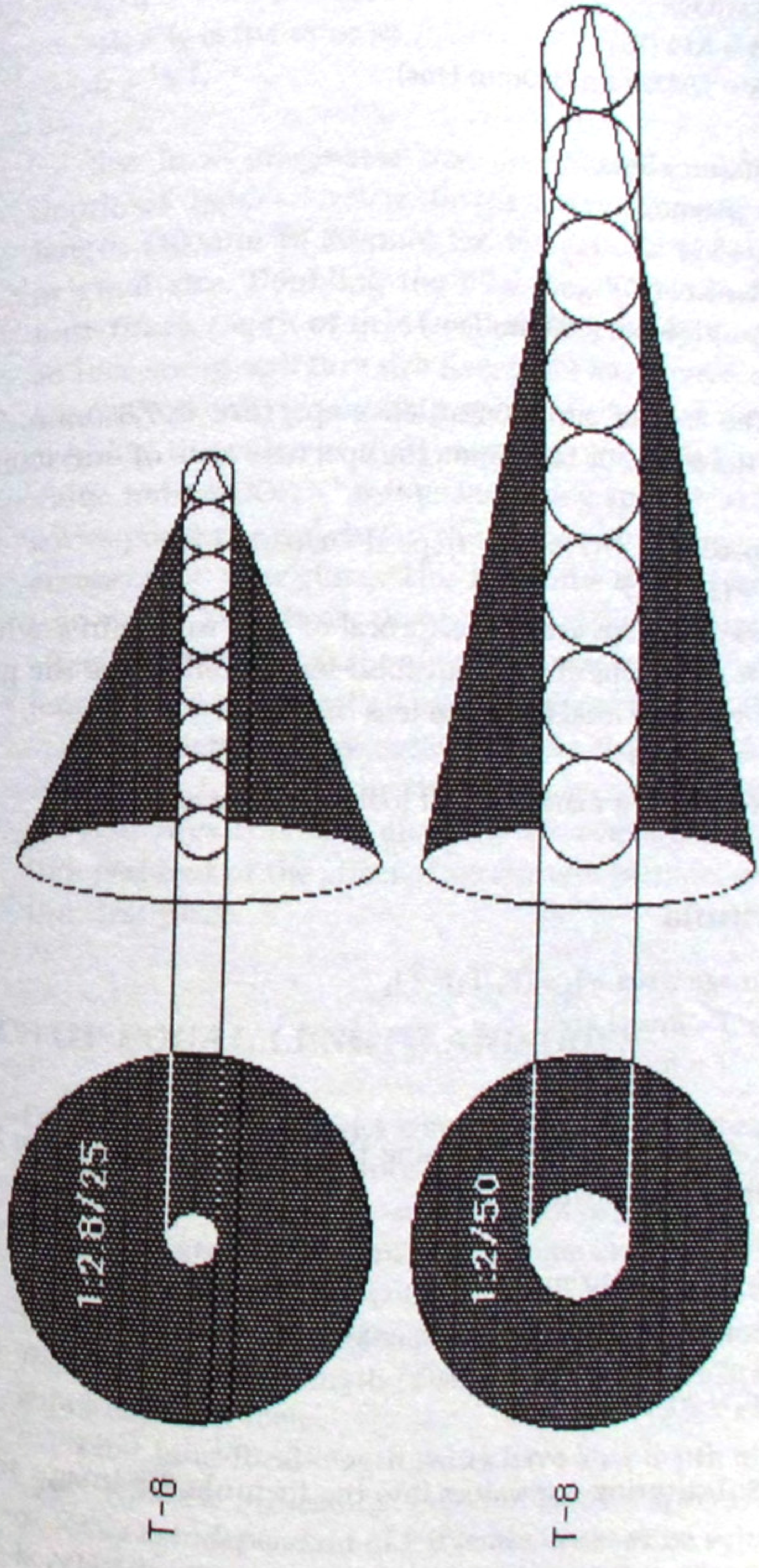


Figure 4-3. Same aperture setting of T8 requires a proportionally larger diaphragm diameter in the longer lens. Lens speed is equal to value of diameter/focal length ratios.

100mm lens:

$r = 25mm$
$\pi = 3.14$
$A = 3.14\ (25)^2$
$A = 1{,}962.5mm$ (100mm lens)

200mm lens:

$r = 50mm$
$\pi = 3.14$
$A = 3.14\ (50)^2$
$A = 7850mm$ (200mm lens)

The area of our 200mm lens's aperture is 7,850mm. This value is four times that of 1,962.5mm, the aperture area of our 100mm lens.

speed = $(d_e)^2/(F)^2$, f#s = 1/speed = $1/(d_e)/(F)^2$
$f = (F)^2/(d_e)^2$
f#s or T-stops are the reciprocal of this, to obtain a whole number.
f#s or T-stops of different-focal-length lenses are the proportional ratios of focal length to lens diameter.

Now, take a mathematical look at image area.

Image Area Formula

Image Area = $I_2 = (F_2/F_1)^2 \times I_1$
I = image area
F = focal length

Let's list our variables, using the 100mm lens and the 200mm lens from the above example.

$I_1 = 1{,}962.5$ (100mm lens)
$I_2 = 7{,}850$ (200mm lens)
$F_1 = 100mm$
$F_2 = 200mm$

Substituting our values into the formula for image area, we have:

$7{,}850 = (200/100)^2 \times 1{,}962.5$ is the same as:
$7{,}850/1{,}962.5 = (200/100)^2$ is the same as:
$1{,}850/1{,}962.5 = (2)^2 = 4$

Substituting back in our variables for diameter values, we have:

$I_2/I_1 = 4$ is the same as:
$4I_1 = I_2$ is the same as:
$I_1 = \frac{1}{4} I_2$

See how image-area size, aperture dimension, focal length, and depth of field all relate. In the above example, doubling our focal length (100mm to 200mm) has increased image area to four times its original size. Doubling the focal length increased aperture diameter four times. Depth of field has decreased to one-quarter its original size. So increasing aperture size four times has decreased depth of field four times. Normally, increasing aperture size four times would mean decreasing the value of the T-stop two times. We know that halving this value halves DOF. This time increasing aperture size to one that would correspond to a halving of the T-stop value (keeping the same lens) decreases DOF four times. This is because of our increase in focal length two times. This shows that aperture size change is not exerting the sole effect on DOF. But at the same time, you can also see that a longer-focal-length lens's necessarily larger aperture reduces DOF.

Focal length may seem to affect depth of field only indirectly. While it's true that apertures of varying diameter restrict entrance only to rays traveling along certain convergence angles, focal length, independent of the effect of aperture, determines convergence angles in the first place.

MECHANICS OF FOCAL LENGTH AND DOF

Focal length determines convergence angles and rays. Designated lens focal length is the distance from the center of a lens to the point where an image point comes to critical focus as an image point when the lens is focused at infinity. But, images come into acceptably sharp focus at a certain distance in front of and behind this point. The distance between these front and back (acceptably sharp) focus points is called *depth of focus*. Short-focal-length "fast" (large-maximum-aperture) lenses have short depth of focus.

That long-focal-length lenses have long depth of focus compared to short lenses is misleading. Depth of focus is aperture dependent. Depth of focus is independent of F if lenses are at same value $N = f/D$, where N is relative aperture, F is focal length, and D is diameter of entrance pupil. Here, depth of focus is the product of $N \times COC$ (circle of confusion). Minimum depth of focus is larger in the long-focal-length lenses be-

cause their maximum aperture is larger. But, when compared to focal length, depth of field in the longer lens may be considered relatively small because the "side of the barn" it presents to bundles of converging refracted rays is at a greater distance and is thus relatively (apparently) smaller.

For objects in front of the lens to fall inside depth of field (object space), the rays emanating from them must diverge within a limited range of angles to be properly refracted by the lens such that they will converge within a limited range of angles and fall within the front and back limits of depth of focus (image space). When depth of focus is long, a larger range of angles of converging rays will focus to a point somewhere along a line drawn between the front and rear limits of depth of focus. Depth of focus is *trigonometrically* larger in shorter focal length lenses.

Long focal length lenses have short depth of field because of size and rate of size change of the vertical angle formed between the lens plane and the refracted converging ray. Converging ray paths "sweep" through depth of focus limits much more quickly in longer-focal-length lenses.

Returning to the "broad side of a barn" analogy, depth of focus is like trying to hit the broad side of a barn while swinging a rifle barrel through an arc and firing at regular intervals. The longer the lens, the farther away the barn is, and the faster you swing the rifle barrel through a larger arc.

The vertical angle is larger in longer-focal-length lenses. Depth of focus occupies a smaller percentage of the vertical angle's usable arc.

The size of the vertical angle changes faster with incremental change in object distance, so converging rays sweep through depth-of-focus limits more quickly over less change in object distance.

Because in a long-focal-length lens the vertical angle is larger, image distance (point of focusing ray) is greater, and it changes faster. This is compounded by the speed of image distance change by more object distance sensitive vertical angles in the longer-focal-length lens. So the point of the converging focusing ray (image distance) spends less time inside depth-of-focus limits.

vertical angle (50mm) is greater than vertical angle (12.5mm)
(angle change/OD) × [50mm] = 4.0231578 × (angle change) [12.5mm]
u[50mm] = approx. 16.8(u[12.5mm])

Size, rate of angle change/OD change, and image distance relate to three properties of the vertical angle that determine the relationship of focal length to depth of focus and depth of field. These are two tangen-

tial properties of the vertical angle and a cotangential property of the vertical angle. This third property drives the first two, which in a circular manner drive the third, which again drives the first two in a constant relationship. See Figure 1-3.

Depth of field is inversely proportional to focal length. Depth of field is less in a long-focal-length lens and greater in a short-focal-length lens for three primary reasons that are found in the three trigonometric properties of the vertical angle.

Because the amount of deviation of the converging ray after refraction (image space) of diverging incident ray (object space), which translates into vertical angle size, the internal vertical angle formed between the refracted converging ray and the lens plane is greater in a long-focal-length lens.

The amount of angular change of the vertical angle varies with focal length and inversely with object distance. This is geometrical in nature. There is a greater rate of change in the internal vertical angle (formed between the lens plane and the path of the refracted converging ray) in a longer-focal-length lens. This rate of change accelerates and decelerates at a greater rate in a longer-focal-length lens, with incremental change in object distance.

The larger vertical angle drives image distance change at a greater rate in the longer-focal-length lens, compared to the smaller vertical angle in the shorter-focal-length lens. These three reasons cause an accelerating increase and decelerating decrease in image focal distance.

This is how lenses of different focal lengths create different depths of field. See Figure 1-3. Now on to some lighter stuff. Is lighter faster? What about the speed of the human eye?

SPEED OF THE HUMAN EYE

The eye has been analogized to a camera lens/film system. The two are more different than alike. We're not here for a physiology lesson, but how about some minor physio-mechanics? The eye has two lenses. Aberration is minimized by the shape of its lens, which tends to ovoid, rather than the lens's spherical shape, and by the curvature of the retina onto which the lens projects. Of the eye's two lenses, the cornea has a focal length of 16mm. Minimum focus distance is 250mm. Between the two lenses is an aperture stop, or diaphragm, called the iris. Its location between the two lenses corrects for positive and negative transverse image magnification (barrel distortion and pincushion distortion). The aperture itself is called the pupil. The pupil can vary from 2mm to

8mm in diameter. So if we use our formula for speed and plug in our variables, listing formula and values first, we have:

Speed = $1/(d_e/F) = F/d_e$
d_e = 2mm to 8mm
F = 16mm
And if Speed = f#
Then f# = 16/8 to 16/2
f# varies from f2 to f8

This is a range of five stops, or a light intensity ratio of 16 to 1.

f2 = 2^0 ($2^0 = 1$ or no stop[change]; the same stop[itself] f2)
$2^0 \times 2 = 2^1$ = f2.8 (two stops)
$2^1 \times 2 = 2^2$ = f4 (three stops)
$2^2 \times 2 = 2^3$ = f5.6 (four stops)
$2^3 \times 2 = 2^4$ = f8 (five stops)
f8 = $2^4 = 16$

The light intensity requiring a pupil diameter of f8 is sixteen times the light intensity requiring a pupil diameter of f2.

f8 = $2^4 = 16$ vs f2 = $2^0 = 1$
Light intensity ratio = 16:1

ASSISTED OPERATOR SIGHTING ON A LONG LENS

The relatively small angle of view of extremely long lenses makes initial sighting of distant objects difficult. It's like walking around at night with a pin-beam flashlight while searching for your subject. You can go right by it in the dark many times before your tiny cone of vision happens onto it. With a long lens, and execs, clients, and crew standing by, sighting can take noticeably too much time. And it can appear noticeably awkward. An assistant can reduce this process to two moves: one pan, one tilt.

First, rough focus the lens. If you think the operator has the object sighted, use a heuristic pull. It's faster than the long-distance estimating technique. Also, your object may be out of range for that technique. This focus does two things in two ways. It focuses the lens approximately, and at the same time, pulling to the "long" end of lens distance maximizes depth of field. An object in focus is easier to spot and less apt to be swept by if the operator insists on "fishing for it." You've made the net (DOF) bigger and the mesh smaller (greater object contrast

through focus). These factors aid in sighting. You can too. You can lead the operator directly to the object. Here's how.

Establish the object's azimuth (horizontal position) first. This is its lateral direction and position along a horizon that has not yet been determined. This is done first because the available range of search (panning) is theoretically a circle. It is much greater than the range of tilt, which is a section of an arc, most probably subtending an angle of 60 degrees or less. Because of this relationship, once the horizontal position is found, the likelihood of losing that is reduced because the available range of space to be searched vertically is much smaller. So the second operation is shorter and the time allowing for potential error is shorter.

To find azimuth, sight over the top of the lens along the axis. Imagine a line along this axis projecting through the center of the lens to infinity. Indicate to the operator whether to pan left or right. When this imaginary axial projection intersects the vertical axis of the object, say "Stop!" You are looking down the axis of the lens toward the object. You probably see the object. The operator probably sees nothing.

Next find the vertical location. This establishes the latitude or elevation of the horizontal plane as it intersects the object. Sight along the side of the lens barrel, again down the projected axis line extending to infinity. Indicate to the operator whether to tilt up or down until our imaginary axial projection intersects the horizontal axis of the object. Say "Stop!" You are looking at the object. The operator is looking at the object. Adjust focus or repull it. By now, your brain has made a few corrections on its last solution and focus will be better this time. It will probably still be rough, but often this second focus will come very close to being very sharp. Why? They haven't figured that one out yet.

LONG-DISTANCE ESTIMATION MODEL

Theory of Model

A selected distance is sighted by a vertex angle that is subtracted from 90 degrees to give an angular difference from 90 degrees. This is expressed as a percent of 10 degrees, which is the angular span of the fist. It is expressed as the same percent of the fist dimension. This gives the distance down from the top of the fist, where sight lines will intersect as they project out to selected distances.

The theory of this model is borrowed from trigonometry. Selected vertex angles, which determine projections of sight lines to selected distances, are found with the use of simple trigonometric functions along with the basic trigonometric tables.

SELECTED DISTANCE (SD) is located by intersection of the ground by sight lines. Selected distances estimated by this model are 300′, 200′, 150′, 100′, 75′, and 50′.

SIGHT LINES are projected (to selected distances) along selected vertex angles.

SELECTED VERTEX ANGLES are found by using the natural tangent function. Correct selected vertex angles are confirmed by the intersection of sight lines (projected along selected vertex angles) with the vertical axis of the fist (held level at arm's length) at selected vertical distances.

VERTICAL DISTANCES represent percentages of the vertical axis. They are located along the vertical axis. They are intersection points of the vertical axis with sight lines projected along selected vertex angles. They locate where sight lines cross landmarks on the fist.

VERTICAL AXIS represents the dimension of the fist. It has a finite length of approximately 5 inches. The vertical axis subtends an angle of approximately 10 degrees (fist held at arm's length).

90° SIGHTS INFINITY, and a sight line, projected at this vertex angle, intersects the vertical axis of the fist at 0 inches vertical distance. This is 0 percent of 10 degrees. This is 0 degrees of angular difference.

ANGULAR DIFFERENCE represents the difference between a 90-degree vertex angle and the value of the selected vertex angle that, at a chosen eye height, will project a sight line to a selected distance. This difference, or result of the subtraction, can be expressed as a percent of 10 degrees. This percent of 10 degrees equals the percent of 100 percent of the vertical distance (entire fist dimension), which is also 100 percent of the vertical axis. This percent locates a vertical distance along the vertical axis where a sight line intersects the vertical axis. The sight line is projected along a vertex angle that, when subtracted from 90 degrees, gives an angular difference. The projected sight line, as it intersects with the ground, locates a selected distance.

This is how to make your own distance estimating model. Inherent in how it works is the necessity for it to be tailored to the variables of your own body dimensions. This is for distances of 300′ to 50′. You must create a model of a triangle with a base (b) 300′ long. The base will be marked at 200′, then 150′, then 100′, then 75′, and then 50′. The height (a) of the triangle will correspond to the user's eye height.

Terms and Definitions

Here are some terms and definitions that will be used in the discussion of the model. They make for quicker reference than extracting their meaning from other parts of the text.

VERTEX ANGLE: Sighting angle.

SIGHTING ANGLE (SA): Vertex angle.

ANGULAR SPAN (deg) (AS°): The number of degrees subtended by a fist held level at arm's length.

VERTICAL SPAN (unit): Vertical axis. The distance subtended by the fist held level at arm's length.

VERTICAL AXIS (VA): A line drawn vertically through the fist (oriented vertically) at its widest point. The endpoints of this axis are at the top and bottom of the fist at its widest point.

VERTICAL DISTANCE (VD): Location, by units, of sight line intersection points. A specified distance along the vertical axis.

VERTICAL AXIS PERCENTAGE (VA%): A percent of the vertical axis.

ANGULAR DIFFERENCE (AD): Sighting angle (vertex angle) subtracted from 90 degrees.

ANGULAR DIFFERENCE SPAN PERCENTAGE: Angular difference expressed as a percent of 10 degrees.

Model Formulas

$AD = 90^\circ - SA$ (angular difference is found by subtracting the sighting angle from 90 degrees)

$VA\% = AD/AS$ (vertical angle percentage is found by dividing angular difference by angular span)

$VD = (AD/AS) \times VA = VA\% \times VA$ (vertical distance is found by multiplying vertical axis percentage by the vertical axis)

This model allows medium to long-range distance estimating by creating imaginary triangles in space. The height of the triangle is determined by one's own eye height. The base of the triangle is determined by the selected distance chosen for estimation. The third leg (c = hypotenuse) of the triangle can be merely laid in, point to point, between the endpoints of the base and height of the triangle. Its distance is actually found by using the Pythagorean theorem. It is almost academic. The first and second legs of the triangle can be used to find the vertex angle (theta or angle b). This is done by working backward through the trigonometric tables for natural tangents. (These tables can be found in the appendix at the end of this book.) See Figure 4-4. These values for vertex angle theta (b), corresponding to distances 300′ to 50′, will give angles of less than 90° for sight lines projected to selected distances. The difference between these angles (in degrees), which sight finite distances (300′ to 50′), and the angle of 90° (which sights infinity) can be expressed as percentages of 10° ($VA\% = AD/AS$). This is the angle

subtended by a human's fist held at arm's length (angular span). Holding a fist level to the eye height and sighting across the top of the fist sights infinity. Sighting down from this point projects sight lines crossing the vertical axis of the fist. Using the percentages of 10° as percents of the dimension of the vertical axis of the fist gives vertical distance down from the top of the fist's vertical axis (VD) that these sight lines must cross as they project to selected distances 300′ to 50′. By noting landmarks on the fist, where these sight lines cross, you can use your body to estimate long distances with great accuracy. After a while your brain, by cybernetic learning, will allow you to skip this technique. Your brain will just know it's looking at certain selected long distances.

Draw Your Body Dimensional Triangle

First measure your eye height carefully. This will be the value for the (a) leg, or height of the triangle with a base that is 300′ in length. Draw this triangle; it helps. See Figure 4-4. You have substituted your eye height for a = 6′ in this figure. Use the Pythagorean theorem to find the hypotenuse (c). This is optional, but it's more complete.

Pythagorean Theorem

The square of the hypotenuse is equal to the sum of the squares of the remaining two sides.

$$c^2 = a^2 + b^2$$

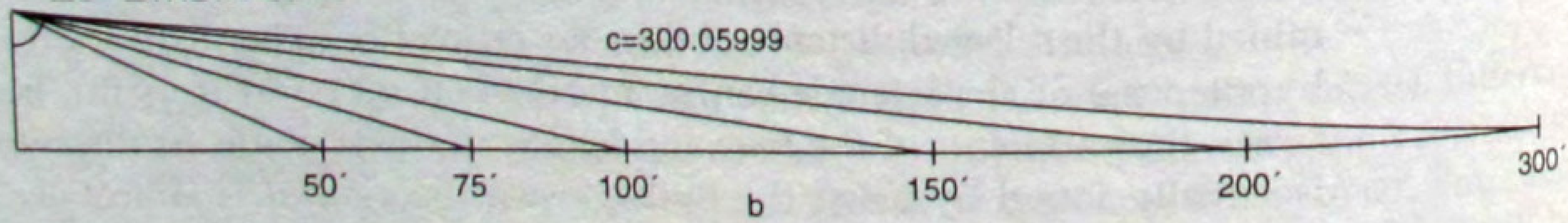


Figure 4-4. Human's eye height forms vertical leg of triangle with a 300′ base.
Pythagorean theorem:

$c^2 = a^2 + b^2$
$c^2 = (6)^2 + (300)^2$
$c^2 = 90{,}036$
$c = \sqrt{90{,}036}$
$c = 300.05999$
$\tan \angle b = \text{OPP}/\text{ADJ} = 300/6 = 50.00$
In the trig table, we find 47.74.
tan 50 (47.74 from trig table) = 88 48″—sights 300″, etc.

So listing and substituting our variables, we have:

c = hypotenuse
a = 6′ (eye height)
b = 300′ (sighted distance)
$c^2 = (6')^2 + (300)^2$
$c^2 = 36' + 90{,}000'$
$c^2 = 90{,}036'$
$c = 90{,}036'\surd$
$c = 300.05999'$

Finish labeling your triangle with distance values and label vertex angle (b).

Angle (b) opens from leg (a) a certain number of degrees that is less than 90°. A distance of 300′ is subtended by angle (b). There are other smaller vertex angles that subtend lesser distances of 200′, 150′, 100′, 75′, and 50′.

Find Lesser Vertex Angles/Sighting Angles (trigonometric functions)

Our next task is to find these lesser vertex angles. They can be found with "trig" functions. These functions are ratios of two legs of a triangle. The value of the ratio determines and/or is determined by the angle opened up by the two legs. To take a short cut, we'll use the tangent function. This is the ratio of the side opposite (desired angle) to the side adjacent (desired angle). We want to find the value (in degrees) of angle (b). It is the vertex angle of the triangle. It is the angle opposite base leg (b). So…

tan = opp/adj and…
b = opposite leg (base) = 300′
a = adjacent leg (height) = 6′

We have:

$\tan \angle b = 300/6$
$\tan \angle b = 50$

Look up 50 in the trig tables under natural tangents. Finding 50 and reading across the angle column for whole degrees and up for minutes, we find:

$\angle b = 88^\circ\ 48'$

This is the value (88° 48′) of the vertex angle of a right triangle with a base of 300′ (selected distance) and a height of 6′ (eye height). So if you stand on the earth and look out at an angle of 88° 48′, you are looking at a spot on the ground that is 300′ away from where you are standing.

Our next distance is 200′. We want to find the value of the vertex angle, at eye height, that subtends a distance of 200′. Using the tangent function, we have:

b = opposite leg (base) = 200′
a = adjacent leg (height) = 6′
tan $\angle$b = 200′/6′
tan $\angle$b = 33.33

Looking up 33.33 in the trig tables for natural tangents (across for degrees, up for minutes), we get:

$\angle$b = 88° 12′

From an eye height of 6′, looking out at an angle of 88° 12′, you are projecting a sight line to a spot on the ground 200′ away.

Our next distance is 150′. The value of the vertex angle at our chosen eye height, subtending a distance of 150′, is found again with the tangent function.

b = opposite leg (base) = 150′
a = adjacent leg (height) = 6′
tan $\angle$b = 150/6
tan $\angle$b = 25

Look up 25 in the trig tables for natural tangents (across for degrees; up for minutes).

$\angle$b = 87° 42′

Looking out at an angle of 87° 42′ (eye height 6′) sights 150′.

Our next distance is 100′. The value, in degrees, of the vertex angle, at our chosen eye height (6′), subtending a distance of 100′, is again found with the tangent function.

b = opposite leg (base) = 100′
a = adjacent leg (height) = 6′
tan $\angle$b = 100/6
tan $\angle$b = 16.66

Look up 16.66 in the trig tables for natural tangents (across for degrees, up for minutes).

$\angle b = 86° \; 30'$

Sighting out at an angle of 86° 30′, at our chosen eye height (6′), sights 100′.

Our next distance is 75′. The value, in degrees, of the vertex angle, at our chosen eye height, subtending a distance of 75′, is again found with the tangent function.

b = opposite leg (base) = 75′
a = adjacent leg (height) = 6′
$\tan \angle b = 75/6$
$\tan \angle b = 12.5$

Look up 12.5 in the trig tables for natural tangents (across for degrees, up for minutes).

$\angle b = 85° \; 24'$

Sighting out at an angle of 85° 24′, at our chosen eye height (6′), sights 75′.

Our next distance is 50′. The value, in degrees of the vertex angle, at our chosen eye height (6′), subtending a distance of 50′, is found again with the tangent function.

b = opposite leg (base) = 50′
a = adjacent leg (height) = 6′
$\tan \angle b = 50/6$
$\tan \angle b = 8.33$

Look up 8.33 in the trig tables for natural tangents (across for degrees, up for minutes).

$\angle b = 83° \; 6'$

Sighting out at an angle of 83° 6′, at our chosen eye height (6′), sights 50′.

Create Sighting Triangle

Having found the angles that at our chosen eye height, sight our selected distances, we need now to find a way to determine that we are

correctly projecting sight lines to our selected distances, at the appropriate vertex angles. There is a simple and reliable way to do this. We'll use the dimensional relationships of our own body features. A fist, held level at arm's length, will serve as an organic protractor.

A fist subtends an angle of 10° when it is held at arm's length. Backyard astronomers have used this convention for years. A fist, with knuckles oriented vertically has a vertical axis of finite dimension, spanning a few inches. See Figure 4-5. The angular measurements of our selected vertex angles can be subtracted from 90 degrees. These angular differences can be expressed as percentages of 10. These angle percentages correspond to distance percentages of the vertical dimension of the vertical axis of a human's fist. Sight lines projected at selected vertex angles, toward selected distances, will intersect the fist's vertical axis at finite distances down from the top of the vertical axis of the fist. See Figure 4-6. These distances down from the top of the vertical axis will be called vertical distances. They locate the point where projected sight line intersection with vertical axis occurs. They serve as sights through which to project sight lines that travel on to locate selected distances. To find these vertical distances (intersection points), we need to know the dimension of the vertical axis of the fist, and we need to know the percentage of this dimension at which the intersection points occur. The percentage of this dimension can be found by translating the angular difference percentage of 10° into a dimensional percentage of 100 percent of the vertical dimension of the fist. Remember, this is a vertical distance that corresponds to the angular span of 10. The top of the vertical axis represents an angular span of 0 and 0% of vertical distance (fist dimension). The bottom of the vertical axis represents an angular span of 10 and 100 percent of vertical distance.

A summary. Vertex angle solutions are subtracted from 90°. They are expressed as a percent of 10° (10° represents the angular span of the fist). These (angular percentage differences) are then converted to like

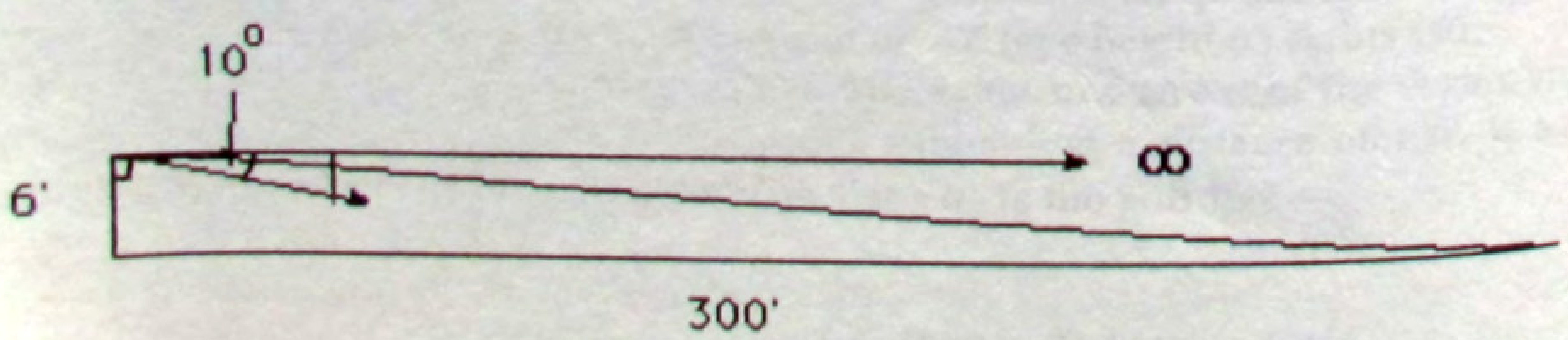


Figure 4-5. Small sighting triangle locates selected distances on large body dimensional triangle.

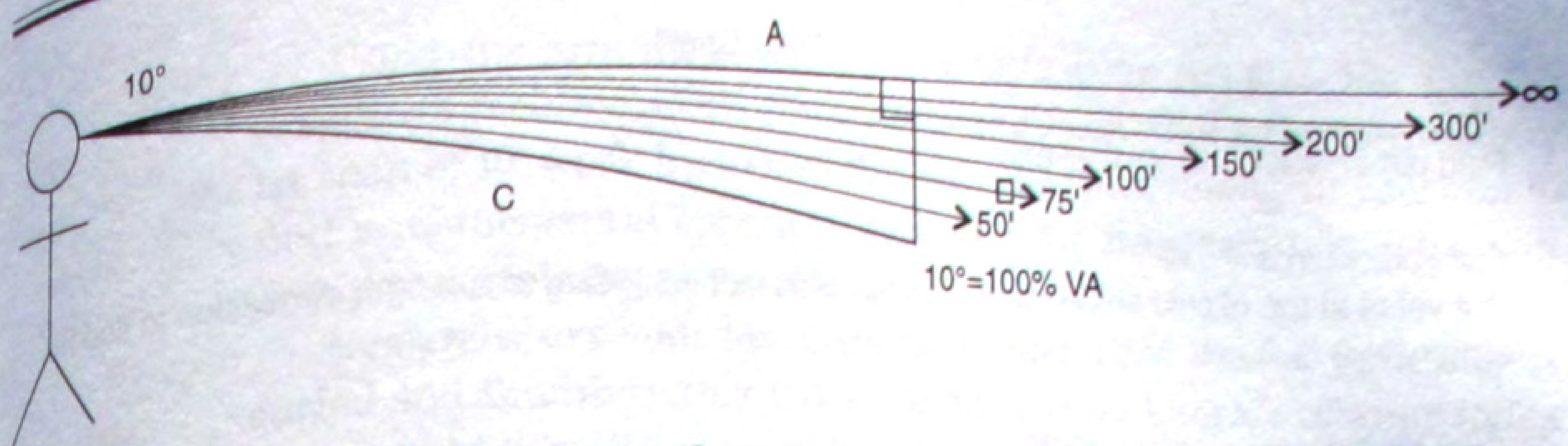


Figure 4-6. Angular differences expressed as a % of 10 degrees (100% VA) determine sight line intersections with vertical axis (VA).

percents of the vertical dimension of the fist. These percents of 100 percent of the vertical dimension (distance of vertical axis) of the fist are our desired vertical distances that locate intersection points for sight lines projected to selected distances.

In creating a sighting triangle using outstretched fist at arm's length, we first need to find two pertinent values. We need to find our fist dimension and to measure our arm's length from a specific point on the body. Both values are derived mathematically and measured directly. After we have found these values, we need to create a chart, like the one in Figure 4-7. It's basically a data chart for our estimation model. Making the chart can come a little later. It is mentioned now, though, because entered into it are the values required for creating our sighting triangle. The values for fist size and arm's length are arrived at by pouring different solutions, from different methods for finding dimensions, all together into a kind of mathematical soup and allowing them to cook down for a while. The different methods and solutions help to "tune" the final numbers we will use for accuracy. Finding these values must be done carefully. Accuracy at the starting point of our model is important to avoid multiplying error into the system.

This is how to make the distance estimating model, broken down into steps.

At the end of this section we'll end up with the angular span of your fist, the vertical axis dimension of your fist, and a value for arm's length. You'll measure the angular span of your fist. You'll use a protractor and/or an angle meter to check the angle subtended in degrees by your fist (measuring from the top of the thumbnail to the bottom of the little finger's second knuckle). If it consistently measures 9° or 11°, this should be considered correct. You will also compute the angular span of your fist. Once you have directly measured the vertical axis of your fist and arm, you will draw a triangle with these dimensions and compute the angle in degrees subtended by the vertical span of your

Model Data Chart

1. Find dimension of fist vertical axis

2. Fist vertical axis = 5.02″
   Put value at top of column D—% of 10/5.02″ (see text on finding axis length dimension to find fist dimension)

3. Find equivalents of vertex angle
   Put in column D

4. Differences from 90° for selected distances converted to percent of first dimension = finite portion of fist dimension in inches

(A) Selected distances	(B) Selected sighting angles (vertex angles)	(C) Angular differences vertical axis from 90°	(D) Percent of angular span/vertical axis % of 10/5.02″		(E) Vertical distance
300′	88°48′	1°12′	12	=	.6″
200′	88°12′	1°48′	18	=	.9″
150′	87°42′	2°18′	23	=	1.2″
100′	86°30′	3°30′	35	=	1.8″
75′	85°24′	4°36′	46	=	2.3″
50′	83°6′	6°54′	69	=	3.5″

Figure 4-7. Model data chart.

fist. After getting the dimensions two different ways, use your best judgment to pick the value to be used in your model. If fist is large or small, use the "better" number. You'll see what this means as you go through the work. Here's how to measure and compute.

Arm and Fist Dimensions (measuring and computing)

First measure your arm's length. One end of a tape or yardstick should start at the triangular muscle pocket on the top of your shoulder. This is called the transverse humeral ligament. Measure from the side of the hollow that is nearest to you. Measure to the tip of your thumb. This measurement is "as the crow flies." If using a soft tape, stretch it tight between the two points. This measurement will come out to approximately half your height, less one-ninth of your height. The distance from the lateral midpoint to the transverse humeral ligament is roughly one-ninth of your height. Repeat this measurement a few times and note the most common result (mode). Don't use a mean or an average. This will make your number too "soft."

Using the arm measurement, compute your fist size. Use the Pythagorean theorem. Using the arm measurement and an assumed angular span of 10, work backward through the natural tangent function to find a mathematical approximation of your fist dimension. This will give you something to shoot for.

Next, measure your fist. Use a clear ruler. Hold the fist with fingers curled and thumb resting flat across the second knuckle of your index finger. Hold your fist at arm's length. This helps prevent parallax problems, because you've reduced sighting angles to their minimum (hopefully, 10°) and reduced error potential to its minimum, as well. Hold the ruler next to your fist, allowing it to rest against the knuckles. The transparence of the ruler helps you to line up unit markings with the top and bottom of your fist. Measure from the top of your thumbnail to the bottom of your small finger. Repeat this measurement a few times and note the most common result (mode).

Now measure the angular span of your fist. Use a protractor and/or an angle meter. If you use both, you can check them against each other. Take the measurement with each several times. Pick your most common result from both (if you use both), and note both (if different). If you get a single mode, note just that.

Now use these physical measurements to develop approximate values for the same variables. You'll then check your physically measured results with your computed results. Comparing them against each other will help you fine-tune the final values you will eventually use in your model. We'll use your physical dimensions of arm's length and fist height to create a triangle, from which we'll compute your angular span (fist), using the "trig" tables for natural tangents. We'll use your directly measured angular span and arm's length to compute fist height, by working backward through the "trig" tables for natural tangents. The computed values give you something to shoot for when measuring, and the measured values help temper the computed values, as they were based on an original arm measurement. These comparisons will give us "best" numbers to use for vertical axis (fist) dimension and angular span (fist). Let's take an example (theoretical eye height of 6 feet).

Compute vertical axis (fist dimension) using:

Arm's length = 28.5″ (measured)
Angular span = 10° (assumed)
Vertical axis = 5.02″ **(computed)**

Measure vertical axis (fist dimension) using:

Arm's length = 28.5″ (measured)
Angular span = 10° (measured)
Vertical axis = 5.5″ (**measured**)

This measured value is different (greater) than our computed value. This indicates the presence of error somewhere. Check your arm measurement.

An alternative scenario might go like this. Here variance occurs in our angular span measurement (9° or 11°). But our **computed** values still work.

Arm's length = 28.5″ (measured)
Angular span = 9° or 11° (measured)
Vertical axis = 5.02″ (**computed**)

This would indicate an error somewhere. Check vertical axis (fist) measurement.

Let's look at a different combination of values using:

Arm's length = 28.5″ (measured)
Vertical axis = 5.5″ (measured)
Angular span = 11° (measured)

Use numbers that are closest to expected result. Look to values that results seem to be pointing to, and/or the mode.

The preceding was an example to support the merit of value comparison in the interest of error detection. The following is an example of working through this part of the model, creating a sighting triangle.

First, we'll find our vertical axis (fist dimension) mathematically, according to our "10°" theory. We'll take an example using a 6′ eye height. You've measured your arm's length (muscle pocket to thumb tip). It measures 28.5″. (This is an approximation that I am using for this example. If you have a 6′ eye height, you'll still have to work through the entire model.) Construct a triangle like the one in Figure 4-8: the (a) leg will be 28.5 inches long; angle (b) will open 10°; the (b) leg represents your vertical axis (fist dimension). Look at this example.

Find (b) with the natural tangent function and the "trig" tables for natural tangents.

tan ∠b = 10°
(a) leg = 28.5″
(b) leg = vertical axis
If tan ∠b = 10°,

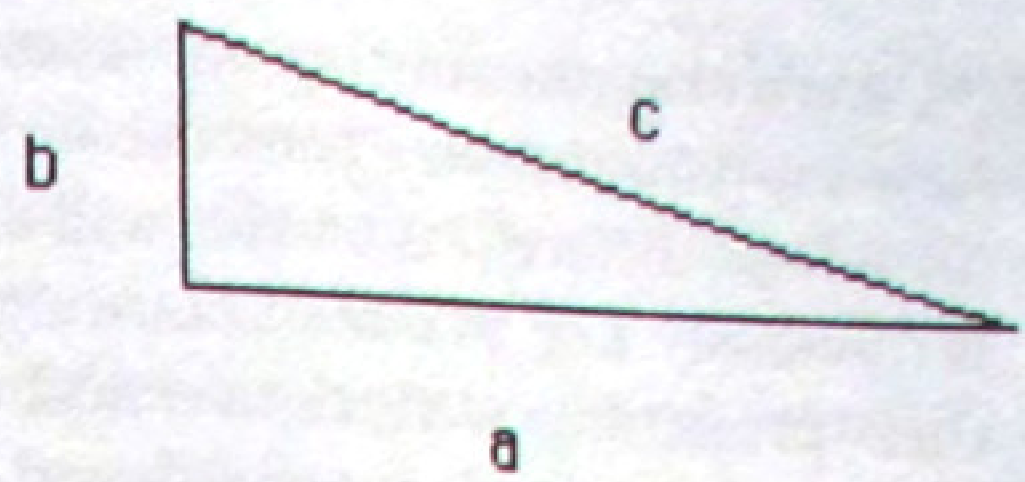
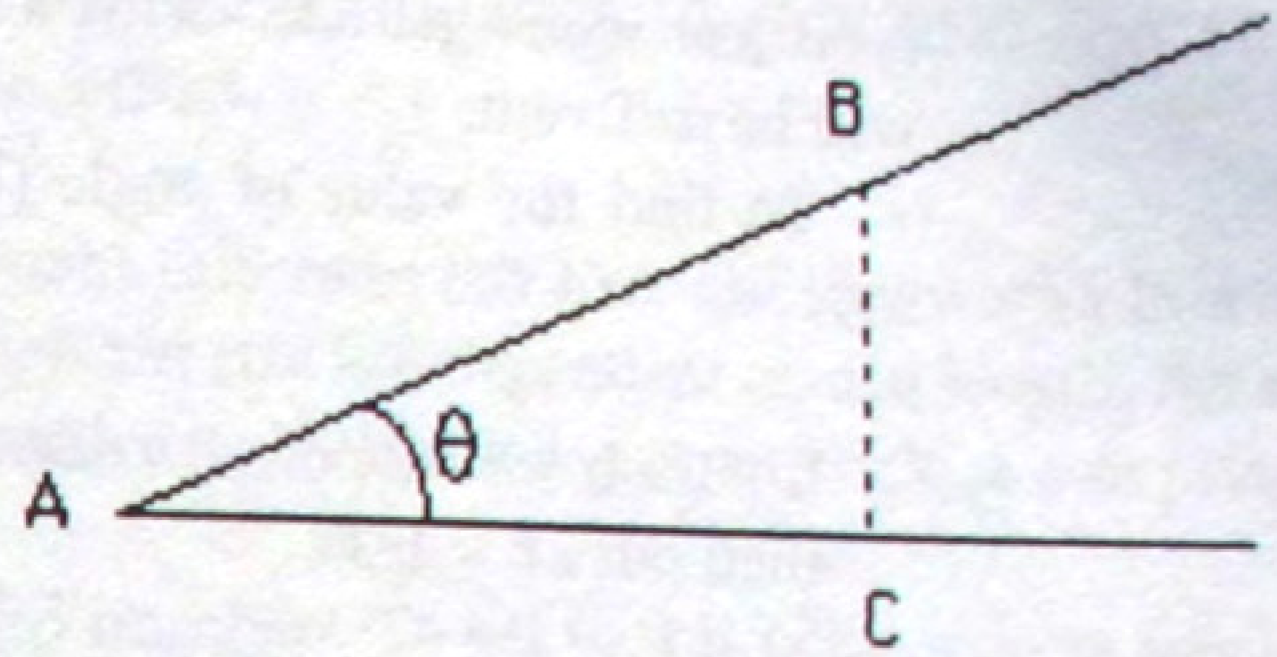


Figure 4-8.



and tan ∠b = b/a,
then tan ∠b = b/28.5″

Looking in "trig" tables for natural tangents, we find that 10° is equal to a value of .1763, so…

if tan ∠b = .1763;
and tan ∠b = b/a,
then .1763 = b/28.5″

Cross multiply:

a × 1 = .1763 × 28.5″ = 5.02″, so…
leg(b) = vertical axis = 5.02″

So, in theory, the dimension of the vertical axis is 5.02″.

Now, measure your fist; you have a value to aim for, but don't fudge. Does the direct physical measurement agree? If you consistently get a different measurement, it is important. Note your mode. Now, let's work backward.

Find the angular span (angle subtended in degrees) mathematically, according to our "10°" theory. We'll use our measured value for vertical axis (fist dimension in inches). Let's say it measures out to 5.02″. So the 10° theory works out. Perfect. Walk away. Go live happily ever after on an island, somewhere. But what if life isn't so perfect?

Let's examine sniffing out error while we're finding angular span. Let's say you measure your fist and it comes out a little different than 5.02″. How different is it? This will affect the angular span result, which is obviously key to our distance sighting angles, as the intersection of their projections with the vertical axis of the fist is determined by a percentage of angular span subtended by the vertical axis of the fist.

Let's say our direct measurement of the fist yields a mode of 5.5″ (you just won't get 5.48″ with a ruler). Your computed angular span will be different.

To find the value of angle (b), use the natural tangent function. So . . .

If tan $\angle$b = X° = opp/adj = 5.5″/28.5″ = .1929824,
then tan $\angle$b = .1930.

Looking this up in the "trig" tables for natural tangents gives:

.1930 = 10° 55′.

This is not 10°. This is significant. Remember the difference between 300′ and infinity is only 1° 12′.

Now, physically measure your angular span (of fist held at arm's length). Use a protractor or angle meter. Do this carefully and repeatedly. What result do you get? Record the mode.

Let's say our physical measurement of angular span still comes out to 10°. There's an error somewhere. Recheck your arm measurement.

Let's say your arm measurement consistently comes out to 28.5″. And let's say your fist (vertical axis) consistently shows a computed and measured value of 5.02″. These compute a span value of 10°. But your direct physical measurement yields a value of 9° or 11°. You've checked and rechecked your arm measurement.

So check your fist measurement. Let's say you now get a measurement of less than 5.02″ or greater than 5.02″ (5.5″). Note this number. Compute span size. Measure span size. So...

Arm's length = 28.5″
Vertical axis = 5.5″
Angular span = 11° (10° 55′)

These are good, well-tested numbers. Note them. These numbers are the values you would use in the model. It should be clear why it is so important to carefully measure your arm's length dimension. This is the foundation value for everything. It's a necessary value that indi-

rectly provides our angular span value, which is our pivotal value. The arm dimension, though it doesn't determine fist size, helps us double-check our span value mathematically. It helps us troubleshoot our physical and mathematical procedure.

To find angular span mathematically, physically, and in turn, to find the "best" span number to use, we've made ourselves a little tool

ARM LENGTH ↔ FIST SIZE ↔ SPAN SIZE ↕↕ SIGHTING ANGLE → DISTANCE ESTIMATION

The arm measurement calibrates our tool. Fist size works in a secondary capacity. Though fist size is independent of arm length, fist size interacts with arm length to give span size. Span angle is our pivotal value.

These are good solid numbers. To get to this point, you've worked hard to get them. And because I've worked hard to get mine, I'm going to use them to finish our example of working through our model.

Example Values
Eye height = 6′
Arm's length = 28.5″
Fist dimension = 5.02″
Angular span (fist) = 10°

Just so you don't think all of this will get away from you, at the end of this walk-through, I'll provide a chart diagram in the section ahead entitled "Technique of Model." This lays out, sequentially, the technique of developing a model for long-distance estimating. This will parallel "Theory of Model."

Now, to find the distances down from the top of the fist (sighted at level arm's length), we must project sight lines across to spot selected distances. Sight lines projecting to selected distances intersect the vertical axis of the fist at specific distances down from the top of the vertical axis. These points are found by taking the angular difference between our sighting angle and 90 degrees and converting it into a percentage of 10 degrees. Ten degrees is the angle subtended by the vertical axis of the fist. This percentage of 10 degrees is also the percentage of the length of the vertical axis we must measure down from the top of the vertical axis (0°/0%) to find the intersection of selected sight lines projecting out to selected distances. Let's start with infinity. All computations are based on the values listed above.

Infinity is sighted from a vertex angle of 90 degrees. The selected sight line for this selected distance intersects the vertical axis of the fist

at 0 inches vertical distance. Angular difference is zero. Angular difference span percentage is zero (angular difference expressed as a percentage of angular span [of fist—10°]). Vertical axis percentage is zero. Vertical distance is zero.

Here's a little math for sighting infinity, or any distance. Sighting selected distances is based on this. It is the relationship between selected sighting (vertex) angles and selected vertical distances.

Selected Sighting Distances (descriptive math)

VERTICAL DISTANCE

90° – SA = AD

90° – Selected Sighting (vertex) Angle = X% × Angular Span = X% × Vertical Axis = Vertical Distance

OR:

(Angular Difference/Angular Span) × Vertical Axis = Vertical Distance

OR:

[90° – SA]/AS × VA = VD

OR:

(AD/AS) × VA = VD

Let's look at finding the vertical distance for infinity in terms of the above descriptions. The selected sighting angle for infinity is 90 degrees.

Vertical Distance (infinity)

90° – 90° (Selected Sighing Angle) = 0 = 0% × 10° (Angular Span = 0% × 5.02″ (Vertical Axis) = 0 (Vertical Distance)

OR:

0°/10° (= 0) × 5.02″ = 0 (Vertical Distance)

Here is the math for finding the vertical distances for our remaining selected distances (300′ to 50′) from our remaining selected sighting angles. Remember, 1 degree equals 60 minutes.

Vertical Distance (300′ [SD])

SA = 88° 48′

90° – 88° 48′ = 1° 12′ so…

AD = 1° 12′ = 72′ so…

(1° 12′/10) × 5.02″ = .6024″ (Vertical Distance) so…

VD = .6024″ (approx: .6″)

Vertical Distance (200′ [SD])

SA = 88° 12′

90° – 88° 12′ = 1° 48′ so…

AD = 1° 48′ = 108′ so…

(1° 48′/10°) × 5.02″ = .9036″ (Vertical Distance) so…

VD = .9036″ (approx: .9″)

Vertical Distance (150′ [SD])

SA = 87° 42′

90° – 87° 42′ = 2° 18 so…

AD = 2° 18′ = 138′ so…

(2° 18′/10°) × 5.02″ = 1.156″ (Vertical Distance) so…

VD = 1.156″ (approx: 1.2″)

Vertical Distance (100′ [SD])

SA = 86° 30′

90° – 86° 30′ = 3° 30′ so…

AD = 3° 30′ = 210′ so…

(3° 30′/10°) × 5.02″ = 1.757″ (Vertical Distance) so…

VD = 1.757″ (approx: 1.8″)

Vertical Distance (75′ [SD])

SA = 85° 24′

90° – 85° 24′ = 4° 36′ so…

AD = 4° 36′ = 276′ so…

(4° 36′/10°) × 5.02″ = 2.3092″ (Vertical Distance) so…

VD = 2.3092″ (approx: 2.31″)

Vertical Distance (50′ [SD])

SA = 83° 6′

90° – 83° 6′ = 6° 54′ so…

AD = 6° 54′ = 414′ so…

(6° 54′/10°) × 5.02″ = 3.5″ (Vertical Distance) so…

VD = 3.5″

The above solutions for vertical distance represent points of intersection of the vertical axis by sight lines projected to selected distances.

The angular span (deg) of 10 degrees is represented by the vertical axis, which measures 5.02 inches. This is represented by the fist.

The fist can be used as a "sight" for selected distances. The fist can be measured for the vertical distance solutions. Hold the ruler against the fist and note landmarks that coincide with the vertical distance solutions. Now, while holding the fist level (this can be learned) and sighting across these landmarks on the fist, one can sight selected distances instantly, from 300 to 50 feet.

A word on "grounding" the technique. After you have developed your personalized model, take it onto a football field (preferably one that isn't being used). First learn to hold your fist level at arm's length. You can learn to repeat this consistently after only a few trials. During the learning process, and as a check, use a stiff dowel rod with an angle meter, or string level, mounted on it. You must also affix a mirror to the dowel rod so you can see "level." Place one end of the rod at the side of the bridge of your nose. This end of the rod will rest against the top of the cheekbone and on the inside corner of the orbit bone of the eye. Let the other end rest along your thumb, as you hold your fist at arm's length.

As you sight across your thumb, you sight infinity. As you lower your look through your range of selected sighting angles, your sight line projects across landmarks on your fist to sight selected distances. These landmarks are again best checked out in a field.

Lay out your selected distances on a field labeled with markers indicating footages on kite sticks. Use your stiff dowel rod with angle meter. Stand at zero feet. Lay the dowel rod from nose to fist. Sight infinity, then lower the fist such that looking across the top of the thumb sights each selected distance. Check the angle meter at each selected distance sighted. Repeat this procedure, lowering the fist by each selected sighting angle. Check the distances spotted. Are they the selected distances? Now, holding the fist level at arm's length, sight across the landmarks you measured out on your fist (vertical distances along vertical axis). Are you sighting the appropriate selected distances? If all checks out, retire the rod. If not, retune. Then practice.

It's theoretically possible that you can eventually dispense with using your fist as a sight. You will just know you are looking at selected distances. This is Zen. From here you can approximate to distances intermediate to selected distances. This is not Zen. It's conscious brain function, but it would not be very Zen of you not to take advantage of this.

Technique of Model

SELECTED DISTANCES CHOSEN
300′ to 50′

TRIANGLE MODEL DRAWN
Base (b) = 300′ (marked for selected distances)
Height (a) = user's eye height (measured)
Hypotenuse (c) (optional) – Pythagorean theorem

SELECTED SIGHTING (VERTEX) ANGLES COMPUTED
Natural tangent function and "trig" tables for natural tangent functions used.
Draw in selected sighting (vertex) angles (optional).

ANGULAR DIFFERENCES FOUND
Subtract selected sighting vertex angles from 90 degrees.

DETERMINE BODY DIMENSIONS
Measure and compute arm's length.

ANGULAR SPAN
Measure and compute—angle subtended by fist at arm's length.

VERTICAL AXIS
Measure and compute—unit measurement (dimension) of vertical axis of fist (oriented vertically and measured top to bottom).
Lock in "best" numbers, comparing for errors and/or variance.

DATA CHART (Optional)
Create a model data chart like the one in Figure 4-7.

VERTICAL DISTANCES COMPUTED
$VD = (AD/AS) \times VA$
$VD_x = [(AD/AS) \times VA]_x - [(AD/AS) \times VA]_{(x-1)}$
$VD_x = VD_x - VD_{(x-1)}$

So:

$VD_{(x+1)} =: [(AD/AS) \times VA]_x + [(AD/AS) \times VA]_{(x+1)} \times [(AD/AS) \times VA]_x$
$VD_{(x+1)} = VD_x + VD_{(x+1)} \times VD_x$

OR:

$VD_{(x+1)} = VD_x + (VD_x \times VD_{(x-1)})$
VD = Vertical Distance
AD = Angular Difference
AS = Angular Span
VA = Vertical Axis
VA% = Vertical Axis Percentage

FIST AS SIGHT (Landmarks)
Note landmarks on fist according to vertical distance measurements.

FIELD TEST
Learn to level arm.
Lay out distances (marked).
Check technique for accuracy with angle meter.
Retune as needed.
Practice.

FOCUS CIRCLES

These are pictures of focus. The focus circles cover an average range of focal lengths, at likely apertures, at lens distances that extend through those used in a classic blocking scheme. The focal lengths covered are 24mm, 50mm, and 100mm. The apertures are T2.8 and T8, for each lens. The lens distances range from 5 feet to infinity.

The universe is ordered in a circle…kinda'. Anyway, a big part of your universe is. Spherical glass to gather light and circles to focus it in. A circle has complex mechanics, yet it's a simple thing. In parallel, complex blocking can often be greatly simplified in its focus requirements. From these pictures you can see that complex blocking, in a scene with actors stopping at six to ten places, can sometimes be reduced to two to four focus marks and points—fast! Less focus pulling also reduces breathing, which is distracting—neat! If you study these pictures your "feel" for focus and depth of field will hopefully become more organic. This is what we are aiming for in this book. No assistant that I know of (myself included) has ever gone really far in this kind of fluent cognitive awareness of depth of field. Is it really necessary to get this good? Maybe not. Is it really Zen to get this good? Definitely yes. See Figure 2-1.

This chapter concludes the technical section of this book. In it, I have tied together all the loose ends of the technical material presented earlier. I hope every gap is filled. We will now move on to briefly treat issues related to being an assistant that are more peripheral and general in nature.

5

Wrap-up

Well, this is where we wrap it all up and put a ribbon on the package. That package is you, and that is what we're going to talk about in this chapter—getting you ready inside and out. We've covered the technical end of the job along a very narrow spectrum: optics and focus in theory and technique. Now we round out your preparedness with the concept of total preparation. The final element is *you*. This will be the most general treatment in the whole book. It will be a very superficial look at physical and mental preparation, clothing, diet, exercise, jet lag, travel, and attitude. It will mix a little philosophy into your shooting, your political encounters with management, and your encounters with yourself when you fail…and you will. How to get back on and stay in the saddle—a lifelong course by Juan Amore Time. We'll try to dispel a few myths. Finally, we hope to send you down from the mountain with something magic to take with you, like a wizard's star. A point of pure light shines from its infinitely distant center. This is yourself opened to finding joy in what you do and that beauty that makes up the mysticism and Zen of your work.

TOTAL PREPARATION

When we talk about total preparation, we add you to the technical loop, completing the circle. Total means physical and mental preparation. The two sides of the same coin have a kind of circular, beneficial effect on each other. A positive state promotes a sense of strong mental well-being. A firm sense of mental preparedness and well-being promotes a good sense of physical preparedness and physical well-being. The positive state of each increases the positive state of the other. Physi-

cal comfort enhances concentration. This often enhances performance. This creates reward, peace, satisfaction, calm, and focus. This translates into a more positive physical state. This slows energy expenditure, delays the onset of fatigue, and allows enhanced physical ability. This creates reward, peace, satisfaction, calm, and focus. This is circular and very Zen.

PHYSICAL PREPARATION

The physical elements of total preparation include clothing, diet, specially targeted physical training and training-targeted diet, and rest. These combine together to make a very integrated, well-grounded, and positive physical sense of whole being (that's you). So kid... wake up and get dressed!

Clothes

Dress for success. This isn't quite what it sounds like. Often, in film work, due to extreme conditions, what looks very uncool is very cool. Well dressed is well prepared, is comfortable, is happy and doing a good job. This is cool. Have clothes on or with you (sport bag) for conditions you expect and don't expect. Be ready for colder weather than you thought, hotter weather than you thought, and weather you never thought of. This goes for working on stages as well as working on exterior locations. Be ready for water and mud, sometimes even indoors. Remember the magic of movies. Make this magic your business and be magic about it. Know the terrain. You'll be walking on it—concrete factory floors to arctic tundra. Have extra clothes. Think about color and fabric. This is not a joke. Think about layers vs heavy clothes. Let's start from the ground up.

Shoes

Hiking shoes, tennis shoes, mud boots... swim fins? From the mountains to the sea, you'll work there.

Hiking boots make great ATVs. They will work on more varied surfaces than any other kind of shoe. The soles are firm, and the boot structure itself also offers good foot and ankle support. The soles protect from loose, pebbly, and uneven surfaces. The boot support reduces energy expenditure and delays fatigue onset. They can work on conventional surfaces, as well. They offer some weatherability in that they are semi-water-resistant.

They have drawbacks. Weight and construction work in a trade-

off. They're heavy and/or often poorly insulated. A strong boot often sacrifices insulation to keep weight down. Even the lightest boot will be heavier than a tennis shoe. The weight factor interacts with fatigue. The high ankle, offering increased support, makes one hotter in warm weather. More body surface is covered. A lighter boot can bring fatigue just as quickly, if not quicker, if it is a colder boot. Wear socks.

Boots are semi-all-purpose. Application is wider than tennis shoes, though, for general work, hiking boots are less practical. Hiking boots should be the first alternative pair of shoes in your sport bag.

Tennis shoes are your primary work shoes. They offer support, and they're good on a lot of surfaces. They provide almost no insulation. They're semi-water-resistant. Mostly, they're hard to ruin and are relatively cheap.

Mud boots are great in wet, tall grass at dawn or dusk. If it rains and it's muddy, you'll really wish you had a pair. Worn with thermal socks, you'll be toasty warm and dry. This means you're comfortable and focused. You won't be watching a clock and waiting for the day to end.

Swim fins are swim fins. If you need some, get some.

Socks

Regular white athletic socks—long ones, short ones, and thermal socks. Take an extra pair of athletic socks in your sport bag, in case you sweat a pair out. Long ones work nicely on colder days. Short socks (footies) work great in hot weather with minimal body coverage. On hard or cold floors, wearing two pairs of socks dampens shock and insulates from cold. Both are fatiguing.

If it's really cold, you'll really wish you had a pair of thermal socks. (Where have I heard this before?) Toasty and warm means comfortable and focused.

Pants (long and short)

Pants should be loose fitting for comfort and ease of movement. This reduces exertion and muscle stress and delays onset of fatigue. Loose-fitting pants accommodate thermal underwear better, and thermals work better in loose clothes that provide dead air spaces. Loose pockets are better than tight pockets.

Color should be considered with the weather and whether you are working indoors or out. Light colors on warm-day exteriors are cooler. Dark colors work well on cold exteriors. Indoors, dark colors are more camera compatible, and radiant light/heat energy is not a factor.

Length is obvious. Shorts that are short cover less body surface, al-

lowing more heat dispersal after conduction. Ease of cooling delays onset of fatigue.

Bush-style pants and shorts are loose fitting and have great pockets. All pants should be 100 percent cotton. It works best with sweat glands.

A note here about fabrics. Until recently, cotton was the best breathing and wicking material for a sweating body. Now there is something Patagonia calls Capilene. It is a treated polyester.

Patagonia pioneered the technology to create a material that is supposed to be superior in its breathing and wicking properties. The polyester is treated with an antimicrobial finish: tri-chloro-hydroxi-diphenyl ether. It acts to break down and inhibit growth of bacteria that thrives in warm, moist environments. This helps keep the fibers and the weave open to pass air and moisture. The outside of the fabric is treated with a hydrophilic finish. *Hydrophilic* means water loving.

The chemistry of Capilene and the hydrophilic outside finish work in conjunction with naturally occurring body heat and the engineering of fiber and weave design to drive moisture from the inner surface to the outer surface. There the treated finish spreads the moisture and speeds evaporation. This increased wicking speeds drying, allowing the body to conduct and convect heat away, as the fabric breathes at optimum capacity.

This technology will be available to other companies in time. For now it is more expensive than cotton, and cotton still does a very good job.

Shirts

Wear what you like. Polo shirts, T-shirts, sport shirts. Sleeve length, color, and collar should be considered according to weather. Choices should be obvious. All should be 100 percent cotton. All should be loose fitting. Extra T-shirts should always be in your sport bag—three, four, or five to change through in hot weather. They can be layered in cold weather. The undermost shirt should be changed once or twice even in cold weather to maintain insulating properties. Remember, hot or cold stress and fatigue interaction.

Extras

Extra clothes can provide a critical difference in hot and especially in cold weather. The greatest heat loss occurs from the head, next from the sides of the torso, then hands and feet.

Extras include thermals (tops, pants, and socks), scarves, sweaters, sweatshirts with hoods, jackets, raincoats with hoods, rain pants, parkas with inner and big outer collars and hoods, gloves (and glove lin-

ers) and hats for shading the neck and eyes, relieving eye strain, limiting head exposure and to preserve warmth.

Thermals obviously provide core insulation and warmth. It's extremely important to wear fresh sets to maintain their insulating properties.

Maybe the most effective single clothing piece, ounce for ounce, is the *scarf*. Along with collars and hoods, they seal the inner core body space, allowing little cold air exchange. If you become too warm, they can be removed instantly, without time consuming redressing off the set. Their portability makes them a most valuable item to have with you if you're far from the trucks. They keep you amazingly warm, even with just a shirt, on cool mornings. Always have one in your bag.

Sweatshirts with hoods add to head insulation when combined with parkas or rain gear with hoods. Even when down and worn with a jacket, they work like a scarf, keeping wind off the neck and out of the warm dead-air space.

Gloves make a huge difference. Work gloves work great with liners. They are practically useless without. Take care to avoid getting them wet. This eliminates any insulating quality. Liners, by themselves, are extremely effective in moderately cold weather. They stash easily in pockets.

Hats and hoods. In hot weather, hats shade the neck and head, but hold heat in. This is a trade-off. They reduce sun exposure, help prevent heat stress. They are very important for fair-skinned individuals. In cold weather they help prevent heat loss from the head, which is the body's primary source of heat loss. And if it is raining in cold weather, keeping the head dry maximizes the insulation effect of dead air spaces provided by the hair layer between head and hat. A hood is an even more effective body warmer than is a hat. Hoods can be layered on sweatshirts, parkas, and raincoats. They keep wind off the body core. They keep water from going under your outer layers and knocking out all your insulation. In cold, wet weather, a warm, dry head makes a difference of night and day on morale, outlook, attitude, focus, and concentration. The day will go a lot faster.

Extra Extras

Sunglasses (green/neutral and red/yellow) with straps, chemical warmers, evaporants, towels, umbrellas, sunscreen, lip-coat, and nose-coat. These should all be in your sports bag.

Have sunglasses in two colors. One pair should be neutral or green. The other pair should have lenses that are toward the red end of the spectrum. The neutral or green glass works well in bright sunshine and contrasty conditions. Full-spectrum light, especially blue light (ul-

traviolet), which scatters more, is transmitted by this color glass to a greater degree. This reduces contrast. This reduces eyestrain, which delays fatigue onset.

Sometimes we want to increase the contrast. Lenses in colors toward the red end of the spectrum accomplish this. Yellow, orange, and red lenses work well in overcast conditions. This creates flat light, minimizing contrast and detail. In flat light, red lenses enhance contrast by reducing blue transmission of scattering ultraviolet light. Detail recognition is important in focus pulling. When using distant landmarks, even varied surfaces tend to be perceived as more homogeneous. Focus pulling on objects moving across relatively homogeneous surfaces gains from enhanced contrast. The other advantage of having two types of colored sunglasses is an obvious one. You have two pairs. This means you have an extra pair if you lose or break one.

Sunglasses of any color reduce squinting. Some say this can reduce energy expenditure by just under 20 percent. This, of course, delays fatigue onset.

Glasses should be on straps. This saves fumbling and helps avoid misplacing them or dropping them. And they're just less likely to be crushed if they're around your neck.

Sunscreen (body, lip, and nose coat) obviously helps avoid the long term effect of UV exposure. Over the course of a career in film, you will work a lot of exterior days, so sunscreen can provide important protection over the long term. Also, and very important, sunscreen provides short-term protection against sunburn. More important than just avoiding the minor irritation of a burn discomfort, sunscreen provides other beneficial effects.

It comes in the form of simple comfort. Again, discomfort is distracting. It impairs concentration and focus. Sunscreen, like anything that increases your comfort level, allows you to perform better longer. Skin exposed to sun all day, even if it is not burned, gets a tight and chalky feeling. It kind of smarts. Stress fatigue becomes a factor. If you are burned, the next day you will be held back in your movement. You don't work as hard because you are "guarding." Also, the discomfort is distracting and de-focusing. Finally and maybe the most important cause-and-effect relationship is rest and sleep. Sunburn's discomfort interferes with good sleep. The next day you are not rested. The poorer performance that goes with lack of rest needs nothing said about it. Sunscreen increases comfort, increases sleep, increases rest, increases peak performance. Again, we're trying to attain a total state of good conditioning.

There is one trade-off with sunscreen. It impairs your ability to sweat. Use it as necessity dictates, on key areas only. Some argue sweat-

ing forces open pores, allowing the body to radiate heat. Sweating also may imply that sunscreen is washed off and rendered ineffective after one good sweat. This makes reapplication important. Avoid this. Use waterproof sunscreen. Reapplication will be less frequent.

Heat packets are a creature comfort with practical applications. Again, increased comfort enhances a general sense of well-being, which enhances powers of concentration and performance. Heat packets offer other practical benefits. They return feeling to cold, numb fingers. This is important when making numerous small adjustments to the camera. You can even put one on top of the movement block in the camera body interior.

They give off heat by chemical reaction. Once activated, the small packets provide significant heat (reaching temperatures of up to 150 degrees) for as long as 12 hours. Small and slim, they fit easily in a pocket or even a glove. They're available in camping stores.

A small umbrella with telescoping handle provides handy cover in rain for your head and/or the camera. Even if you have head gear and camera covers, an umbrella keeps a lot of weather out. Umbrellas provide good shade in extremely hot, sunny environments. It's a good wind stop, as well. It can quiet things down for an operator. It can quiet an image down for a long lens. When choosing a small umbrella, open it. Some are too small. Get the one with the biggest "chute" you can find. Don't buy the cheapest one. They break the first time out. A little more money means the difference between an effective weatherproofer and a useless cobweb of broken metal and torn fabric. By the nature of an umbrella's design it's delicate, and by the nature of its use it's going to take some punishment.

Sweat is a good evaporant. As it evaporates from skin surfaces, it cools the body. Sea Breeze is another example of a surface cooling liquid. Its first contact is refreshing because of its composition. It can be kept in ice water. It can be cut and mixed with ice water and applied in a mist from a spray bottle. Its astringent nature helps to keep pores open and free of clogging fats, grease, and dirt. This maximizes the body's ability to sweat naturally. Use it liberally. Saturated astringent towelettes in packets are a good portable form. They can ride in your camera bag.

A word here about attitude in the heat. Learn to enjoy the heat and being sweaty. Strip down and get hot and wet!

One or two hand-size towels work well in wet, hot, or dusty weather. You can wipe yourself and the camera off with them. Washcloths are a handier size, but they get used up quicker. In hot weather, wipe off layers of sweat and grime and then spray with Sea Breeze.

Earplugs cut down noise, which is a stressor. Cut down excessive

(high-decibel, high-frequency, and large-amplitude-wave) noise and you cut down stress. This delays fatigue onset. Over the long term, extreme noise exposure can cause temporary and permanent nerve damage.

Carry all this stuff in a sport bag. It allows you to be ready for changes. Extra clothes allow you to stay fresh, comfortable, and focused. Weight the contents toward the expected environment and weather conditions: hot/cold, wet/dry, windy. Are you shooting in a desert or in Alaska? Not all deserts are hot. Be prepared for both. Are you working on a river? Is rain expected? What if it happens anyway? This means provide for the unexpected weather, as well. Here's a general content profile to start from. This applies to stage as well as location.

Sport Bag

Extra shoes—by terrain and weather
Extra socks
Extra pants—long or short by weather
Extra underwear—if extremely hot or cold or wet
Extra shirt(s)—by weather
Extra T-shirts—if extremely hot or cold; or wet
Rain gear—jacket (hood) and pants
Rain boots
Sweatshirt (hood)
Parka (hood)
Thermals—shirt, pants, and socks
Hats/hoods
Gloves
Glove liners
Scarf
Sunglasses—two pairs (different color lenses)
Heat packs
Umbrella
Evaporants
Towels
Sunscreen(s)
Creature comforts (psychological and physiological lift)—book, magazine, fruit juice, jerky, special tea (ginseng), gum, etc.

Make one final addition to the contents of your sport bag: the contents of your pockets and your wristwatch if you wear one. Keys, change, money, etc., are things you don't need to shoot. You're less likely to lose your car keys. This can be disaster at a distant location. Empty pockets will make you feel less distracted. Empty pockets allow

you to feel more comfortable. Take your wristwatch off too. Not having these trinkets of everyday reality on your person will accentuate your sense of "being there" and will help keep your mind focused on the "here and now" of shooting.

Diet

You are what you eat, right? So eat better, be better. This is a very nontechnical treatment of nutrition. Food can affect mood, behavior, and performance. We are going to exploit this knowledge to maximize energy storage, availability, utilization, and endurance.

By now it will sound cliché and it will be simplistic. There are whole books on this subject, so I'm not going to write another one here. Use carbohydrates, manage your fluids, and moderate alcohol and caffeine.

Carbohydrates

Carbohydrates should constitute a maximum of 60 percent of the human diet. These are grains, vegetables, and fruit. Sugar, as opposed to being a complex carbohydrate, is known as a refined carbohydrate. These are sweets and pastry. The first three categories make a base for a healthy diet. Their percentage of your total dietary consumption should be increased before and during shoot days. A high percentage of refined carbohydrate (sugar and sweets) in the diet can cause stress and disease.

They're fun, though, and you shouldn't live like a monk while you work, unless you enjoy it. But, moderate them, especially before and during shooting days.

High-carbohydrate diets prevent glycogen depletion, which shows as chronic fatigue and inability to maintain normal intensity of performance levels. A high-carbohydrate diet (70%) can restore glycogen to normal levels in 24 hours. A 70 percent carbohydrate diet is recommended to athletes when they are exercising hard. This is for heavy training. You will moderate this. You cannot take quite as high a percentage of sugars.

Emphasize complex carbohydrates: fruits, vegetables, whole-grain breads, cereals, pasta, and legumes (especially beans). Deemphasize refined carbohydrates. Complex carbohydrates are starches. Complex carbohydrates facilitate glycogen storage to a greater degree than do refined carbohydrates. In the first 24 hours after great exertion, there is no difference between complex and refined carbohydrates. By 48 hours, complex carbohydrates promote significantly greater glycogen storage.

The four food groups, taken in balance every day, provide a balanced diet. During heavy physical exertion, you may increase the serving numbers from four all the way to eight to keep CHO% of diet at recommended levels. See Figure 5-1.

Carbohydrate loading is effective only if you are endurance trained. Endurance training means continuous exercise for periods of 90 minutes or longer, 3 to 5 days a week. Stiffness and heaviness from increased glycogen stores can hurt performance of shorter duration. You do not exert like an athlete, but you can modify your diet to beef up your margin of CHO and glycogen stores before and during a shoot. Increased CHO stores won't allow you to work harder, but they will enable you to maintain a pace for a longer period; endurance.

Now let's get even more general. People tend to get drowsy after lunch. This natural low point in the human circadian cycle is sometime called the postprandial blues. Eating a smaller meal helps avoid this. Eating less red meat helps avoid this. Eating fewer sugary sweets helps

	RECOMMENDED SERVINGS		
FOOD GROUP	Child	Teen	Adult
DAIRY 1 cup milk, yogurt 1.5 oz cheddar cheese 1 cup pudding 1.75 cups ice cream 2 cups cottage cheese	3	4	2
PROTEIN 2 oz. cooked lean meat, fish, and poultry 2 eggs 2 oz. cheddar cheese	2	2	2
FRUIT/VEGETABLE .5 cups (cooked or juice) 1 cup raw (1 avg. size piece of hand-size fruit)	4	4	4
GRAIN, WHOLE GRAIN, FORTIFIED, ENRICHED 1 slice bread 1 cup ready-to-eat cereal .5 cups cereal (cooked), pasta, grits	4	4	4

Figure 5-1.

avoid this. High-protein meals are often high-fat meals. High-protein meals are harder to digest. You become drowsy. High-carbohydrate meals tend to be low-fat meals. High-carbohydrate meals are easier to digest. You don't get as drowsy. Moving from sugars to fruits to vegetables to whole grains, the energy provided is less "peaky" in nature and longer lasting. See Figure 5-2.

Super Carbohydrates

Rice is an excellent, slow long-term energy burner. Beans are high CHO and high protein. They are low fat. Peas are the same. Starchy vegetables include corn and potatoes. See Figure 5-3.

Fluids

Fluids are an obviously strong factor in endurance and performance. Alcohol and caffeine (most often in liquid form) are treated separately, in that their effect is not related directly, or at least simply, to water replacement. Water absorption, loss, and replacement are directly affected by fluid management.

Fluids are "huge." Your body is mostly fluid. Most of this is water. Water is the best choice in fluid management. Water is essential for energy production, temperature control, and eliminating metabolized waste products.

The obvious effect of poor fluid regulation is dehydration. This reduces endurance. A feeling of fatigue in the later stages of prolonged exertion may be due as much to dehydration as to depleted energy

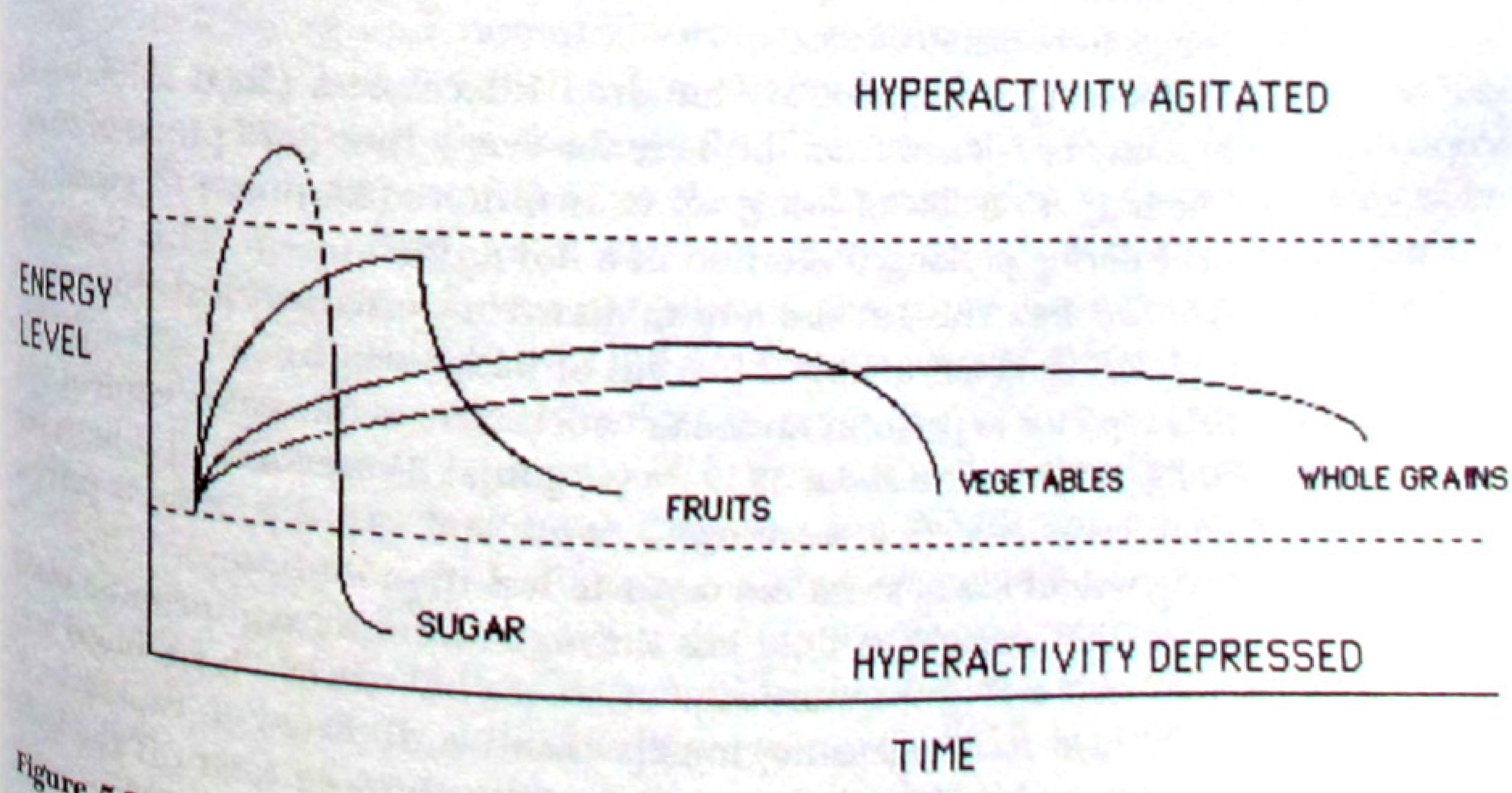


Figure 5-2. Energy-level curves for various forms of carbohydrates.

STARCHY CARBOHYDRATES

Wholemeal bread flour and crispbreads
Wholemeal pastas, brown rice
Pulses and legumes: peas, lentils, beans (kidney, haricot, baked beans, etc.)
Pearl barley
Potatoes, sweetcorn, root vegetables
Cereals: Weetabix, Shredded Wheat, Branflakes, Puffed Wheat, porridge, sugar-free muesli
Nuts: peanuts (unsalted), brazils, hazelnuts, chestnuts, almonds
Fresh fruit: apples, pears, oranges, bananas, grapes
Dried fruit: currants, sultanas, apricots, prunes, etc.
Tinned fruit in natural juice

SIMPLE SUGARS

Sugars, syrups, jams, marmalades
Confectionery: boiled sweets, chocolate toffee, fudge, etc.
Sugary drinks: lemonade, cola, squashes, blackcurrant
Drinking chocolate, malted bedtime drinks
Sugar-coated cereals, sugary cakes, biscuits, pastries, fruit pies and crumbles, jellies, cheesecake, ice cream, fruit yogurt, tinned fruit in syrup, sweet custard, milk puddings, sweet pickles

Figure 5-3. Super carbohydrates.

stores. Dehydration can and does promote a diminished mental state, impairing judgment. Dehydration increases risk of heat illnesses like heat exhaustion and heat stroke. One way the body can become dehydrated is by the protective mechanism of heat loss through sweat evaporation.

The sweating mechanism is called upon, by the body, as heat production increases beyond the point where radiation, convection, and conduction serve as adequate means of heat (loss) regulation for body temperature maintenance.

Sweating is adaptive. Six hundred kilocalories (2500 kilojules) of heat may be released from the body for every liter (1.75 pints) of sweat. The body is capable of losing up to two liters (3.5 pints) of sweat per hour during prolonged exertion in a hot environment. This is significant heat loss. This can also lead to disastrous effects if lost fluid is not replaced. Fluid loss of only 2 percent of body weight can seriously impair capacity to perform muscular work. The total water content of a 70-kg/154-lb man is about 23 liters (40 pints). Water loss of 2 liters per hour becomes a very meaningful "number." At this rate, 2 percent body weight loss in sweat can occur in less than an hour.

Critical amounts of fluid loss through sweating compromise blood circulation and temperature regulation. If you exert in heat, blood normally used for oxygenating muscle tissue is diverted to capillaries at the skin surface. The obvious purpose is to conduct heat off the body core. This competition for blood puts extra stress on the cardiovascular

system, which works harder to maintain requisite blood oxygenation levels to muscles. So dehydration increases heart rate. As sweat loss exceeds replacement, the circulation system can't keep up. Blood flow to the skin falls off. This is in an effort to maintain plasma volume. Plasma volume ensures the heart's ability to maintain high-volume blood flow throughout the working body. Sweat is basically blood. As it is lost and not replaced, blood volume drops, as the water portion of the blood component decreases. With the drop in plasma volume, the amount of blood pumped by the heart (stroke volume) drops. Heart rate increases to try to maintain operating levels of heat radiation through cooling by subdermal blood flow and to maintain acceptable oxygenating levels to muscle. Eventually there will be a sacrifice.

Skin blood flow is sacrificed. Muscle oxygenation takes priority. Sweating capacity is reduced, with an accompanying inability to lose heat as exertion continues. Core temperature can soar to 41° Celsius (105° Fahrenheit). Performance falls off and a dramatic increase in effort is required to maintain exertion level. You may not even feel hot at this time. You may not even feel thirsty, though you are definitely behind on fluids. Inadequate fluid intake to replace fluids speeds dehydration and escalates this entire process. Increase hydration to avoid dehydration.

Practice prehydration. Twenty to forty minutes before exertion, drink 250 to 600 ml (10 to 24 oz) of cold water. This helps keep core temperature down and reduces heat stress on the cardiovascular system.

Maintain hydration. During exertion drink 75 to 150 ml (3 to 6 oz) of cold water every 10 to 15 minutes. This rate is related to gastric emptying and rate of absorption. It is compatible with absorption rate of the body, which is key. It's not how fast you drink, but how fast it is absorbed by the intestine. The same holds true for quantity. Larger amounts empty from the gut faster, speeding hydration, but may cause discomfort. Cold water empties to the small intestine faster than hot water: cold does not harm the heart and does not cause cramping. The ideal temperature is 8 to 13 celsius (46 to 55 Fahrenheit).

Concentrated solutions (anything other than pure water) empty slower and are absorbed slower, as well as later. They can even stop absorption and cause fluid loss and dehydration by reverse osmolality. Concentrated solutions can cause cramping.

Thirst is a poor indicator. By the time you feel thirsty, it's already too late. Fluids lost cannot be absorbed and replaced fast enough.

Kind of fluid is important. Some fluids empty faster from stomach to intestine, where they are absorbed sooner and may be faster than others. This brings us to sports drinks.

Sports Drinks: Sports drinks are just water supplemented with carbohydrates and electrolytes. Carbohydrates are used up in periods of exertion by glycogen depletion and fatty acid metabolism. Electrolytes are lost as the body sweats. Sports drinks boast their value in carbohydrate and electrolyte replacement. No case can be argued for the short-term beneficial effects of replacement of these two substances. Replacement offers no tangible augmentation to performance or endurance, nor is performance or endurance diminished by lack of replacement.

Carbohydrates in sports drinks are in the form of glucose. A concentration of glucose greater than 3 to 5 percent dramatically slows emptying. Sports drinks range in glucose concentration from 4 to 7.5 percent. Remember, more concentrated solutions are more likely to cause cramping, something sports drink manufacturers claim their ingredients protect against. Why bother? Glucose concentrations of less than 3 to 5 percent provide carbohydrate levels that are too low to make a significant contribution to energy provision during exertion. Due to the "peaky" nature of the energy provided by glucose (see Figure 5-1) and the fact that carbohydrate replacement only shows an effect over long-term exertion periods, glucose is limited in its usefulness as a carbohydrate. Sugary drinks have, however, been shown to improve performance in exertion periods of over 90 minutes. But the carbohydrate as sugar requires constant replacement. Some studies have shown other carbohydrates to be delivered to the intestine (emptied) faster than others. They too, however, require constant replacement. Some sports drinks utilize glucose polymers instead of glucose.

Glucose polymers are small glucose chains made by breaking down cornstarch. Drinks using these polymers show rapid absorption properties. Concentrations of 5 percent glucose polymers and 2 percent fructose allow these drinks to be absorbed as fast as water. Sports drinks using glucose polymers have concentrations ranging from 6 to 16 percent. Studies have also shown that glucose polymers may slow the rate of muscle glycogen depletion—this is what leads to fatigue. Glucose polymers, like glucose, require constant replacement. One study recommends consumption of .25 grams carbohydrate/kilogram body weight for every 30 minutes of exertion. For our 70-kg/154-lb man this means 17.5 grams carbohydrate or 9 oz sports drink every half-hour. This is a lot and may cause discomfort.

Electrolytes that are lost in sweat do not need to be replaced immediately. Loss or replacement makes no difference in performance or endurance. Electrolytes are constituent trace elements of minerals like salt (NaCl) broken down into separate ions (Na^+ and Cl^-). With other trace elements like copper, zinc, and fluoride, they form components of bone,

connective tissue, hemoglobin, hormones, and enzymes in the body. Long-term depletion causes much more basic and serious complications like circulatory failure from reduced plasma volume. Short-term depletion is not harmful to the body or detrimental to performance or endurance. Sports drinks, in their advertising, leave it to your imagination that replacement is somehow important.

"...Replaces lost electrolytes!" So what? Some manufacturers claim electrolyte replacement helps prevent cramps. There is no evidence to support this. To the contrary, concentrated solutions increase the likelihood of cramps.

A high enough concentration can actually contribute to dehydration. High concentrations of electrolytes can slow fluid absorption in that the hypertonic state they create increases molality in the wrong direction. Water is lost as it comes out of the body into solution, attempting to stabilize osmotic potential. There is some evidence that low concentrations of electrolytic salt (Na^+ and Cl^- ions) promote fluid absorption in the intestine. So sports drinks are merely fluid replenishing drinks. Low calorie drinks are absorbed faster.

Given all the factors, the purest, least-concentrated, lowest-calorie drink is the best drink. So the best sports drink for fluid replacement is still pure cold water. Sorry guys...

Alcohol: Obviously, no one takes alcohol to extend endurance or heighten performance. Some people use it to relax, even at breaks between work, like at lunch. Some people skip the breaks altogether and use it at work. Life is just one long party or hangover, however you look at it. But that's a different book. Anyway, the problem with alcohol is one of lingering effect. Some use alcohol to warm up or cool off. Like the sense of well-being it can provide, these are only illusions. Illusions given at the expense of the exact opposite physiological effect. Consuming alcohol in cold weather is a perfect example of this.

Alcohol makes one feel warm while actually chilling the body. When alcohol is taken into the body, the blood vessels of the skin dilate, increasing blood flow at skin surfaces. The perceived effect is one of a warm body glow. As heat is conducted away, the blood is cooled and eventually leads to a drop in body temperature. In cold weather, the body must now expend more energy in trying to warm itself. This speeds the onset of fatigue.

Alcohol is a potent diuretic. It promotes dehydration. Alcohol inhibits the liver's ability to maintain high glucose levels by gluconeogenesis. This is the production of glucose from compounds other than carbohydrates, such as proteins. This impairs optimal physiological

states for exertion. This is true for consumption of large amounts of alcohol even 12 hours before exertion.

The biggest thing about alcohol is judgment, which is one of the first things to go out the window when you use it. The people who are going to sabotage themselves and maybe the safety of others in the workplace will ignore this section. The people who won't probably didn't need to read what's written here, anyway. But what's true for everything in this final chapter is that it's all your judgment call. As far as alcohol goes, here are the facts; use your best (worst?) judgment.

Caffeine: Caffeine definitely alters behavior. Can moderate amounts of caffeine improve performance? Caffeine has been proven to augment performance for some people in some circumstances. It doesn't work for everyone. Caffeine works by shifting the percentage of body fuel consumption to a different source. Remember, glycogen depletion impairs endurance. Caffeine shifts the body from glycogen-depleting carbohydrate metabolism to oxidation of fatty acids. Caffeine is ineffective in high-intensity, short-duration activities of 10 minutes or less. It is effective in improving prolonged endurance activities. Muscles will utilize usable fat available at high levels. This spares glycogen. It is possible that caffeine consumed before exertion may increase availability of usable fat.

Caffeine appears to increase endurance and intensity. Caffeine has been shown to increase endurance by 20 percent. Subjects in the experiment reported the work was perceived as "seeming easier." This is possibly due to the fact that caffeine is a central nervous system stimulant. Another study showed production increased by over 7 percent.

Optimal results are achieved by levels of 4 to 5 mg of caffeine/kg of body weight, taken one hour prior to the exertion period. For someone of roughly 150 lbs body weight, this works out to approximately 330 mg caffeine. This dosage is approximated by two to three 6-oz cups of *black* coffee. (The body's insulin response to increased glucose levels due to milk and sugar would negate the effect of the caffeine.) See Figure 5-4.

Additional amounts of caffeine do not enhance the effect. Overdosage may result in caffeine toxicity: nausea, muscle tremor, headache, nervousness, anxiety, and just a general feeling of being wired. This state is obviously counterproductive to optimal performance.

Targeted Exercise and Targeted Diet

The proper state of physical preparedness stressed in this book is one of hyperhealth. Most individuals are adequately healthy. Most individuals are not assistants (or grips, gaffers, electricians, etc.). This book is not

Food Sources	Dosage
Coffee (6-oz cup)	
Espresso	180 mg
Drip	132–180 mg
Perk	76.8–149 mg
Chocolate (6 oz)	
Baker's	210 mg
Bittersweet	120 mg
Milk chocolate	36 mg
Cocoa	10 mg
Tea (6 oz)	
Black tea	60 mg
Green tea	36 mg
Instant tea	36.6 mg
Soft Drinks (6 oz)	
Jolt Cola	36 mg
Diet Mr. Pibb	29.5 mg
Mountain Dew	27 mg
Mello Yello	26.5 mg
Tab	23.5 mg
Diet Coke	23 mg
Coke	23 mg
Diet Shasta Cola	22 mg
Shasta Cola	22 mg
Shasta Cherry Cola (Diet)	22 mg
Shasta Cherry Cola	22 mg
Sunkist Orange	21 mg
Mr. Pibb	20.5 mg
Diet Dr. Pepper	20 mg
Dr. Pepper	20 mg
Big Red	19 mg
Pepsi	19 mg
Pepsi Light	18 mg
Diet Pepsi	18 mg
Diet Rite Cola	18 mg
Royal Crown Cola	18 mg
Jamaica Cola (Canada Dry)	15 mg

Nonfood Sources	Dosage
Stimulants (per tablet)	
Vivarin	200 mg
No Doz	100–200 mg
Diuretic	
Aqua-Ban	200 mg
Permathene	200 mg
Weight Control/Diet	
Dexatrim	200 mg
Dietac	200 mg
Prolamine	140 mg
Analgesics/Menses (symptom relief)	
Excedrin (extra strength)	130 mg
Excedrin	64 mg
Pre Mens Forte	100 mg
Pre Mens	66 mg
Midol	65 mg

Figure 5-4. Sources of caffeine.

for most individuals and it's not for most assistants. This book is for the "hottest" assistants (or grips, gaffers, etc.) or the ones who want to strive for that. This book is for those who want to try very hard to strive for something just a little bit better. This book is about "assisting" and the assistant at a little bit higher level, maybe even a Zen level. So it's okay

for the family car to be adequately healthy. See yourself as a finely tuned, exotic machine that is "race prepared." Above-average health is achieved through exercise and exercise (and exertion) targeted diet.

Exercise on a regular basis. This allows for the maintenance of a good base physical state. It is recommended that this normal good conditioning be elevated to a slightly enhanced physical condition before a shoot. Step up your exercise program just before a shoot and make it a bit more specific.

Tailor the kinds of exercise you do to enhance those parts of your body that will be used more on the shoot at hand. Covering a sporting event can often involve much walking, sometimes over a lot of different outdoor terrain. 16mm cameras are usually used. They're relatively light and easy to carry. This means effort will be more directed toward the lower body.

Emphasize lower-body training—leg exercises, etc. Endurance will probably factor in. Program exercises in this direction as opposed to short bursts of power. Increase general endurance training, as well. And finally, add emphasis to one part of your general upper-body program: the forearms.

Additional forearm strength has good application with 16mm cameras. Greater in size and weight, 35mm cameras are lifted with more of the body. The smaller size and weight of 16mm cameras take more use of the wrists and hands. The muscles for these areas are the small muscles in the forearms. Of course 35mm shoots make different demands on the body.

When preparing for a 35mm shoot, the upper body is stressed in training in anticipation of the shoot. These are often studio shoots with little distance walking involved. Even on location, the camera and crew cover less ground. The camera is twice the size and up to three times the weight of a 16mm system. Lifting is a bigger part of your day. The greater mass and size also involve more muscle groups of the back. Hand grips are larger. This reduces use of small muscles for wrists and hands. More large muscles of the arm are used.

Some lower-body training should still be emphasized. Because of the size and weight of the camera, more muscles throughout the body are used. Heavy weights are properly lifted with the legs.

Endurance vs power is a mixed issue with 35mm. Standing for 12 hours takes endurance. The physical moving of the camera between setups calls for short bursts of increased power.

A 16mm camera is often carried around for great distances for a long time: endurance. A 35mm camera is often moved on a dolly: and sometimes a 35mm crew is large enough so one of the grips might carry the camera. British crews do this more than American crews. The switching of legs, heads, addition of risers or a difficult placement on

legs or high hat calls for greater exertion for a shorter time; power. Program exercises in the direction of power. Increase general endurance training, as well.

Diet for the nonathlete has a reduced effect, but still adds an edge and can be targeted for the nonathlete who trains for a shoot. The nonathlete cannot take advantage of carbohydrate loading. This is because muscles that are not endurance trained will not store more than their usual amounts of glycogen. You will probably not train at levels required to stimulate muscles to "load" extra glycogen stores, when given the opportunity. (Endurance training isn't the commitment it sounds like: exercise periods greater than 90 minutes for 3 to 5 days a week.) Still, increasing carbohydrate consumption assures the nonathlete of maximum glycogen stores and reduces the percentage of less well used nutrients, like proteins and fats.

Start ahead of the shoot. Four days before your shoot, increase carbohydrate intake from an average of 45 percent (normal American diet) to 70 percent (heavy training diet). You should be careful about weight gain, but your exercise should be increasing too. You may not be able to take as much sugar into your diet as a training athlete. This may lower your CHO percentage to 60 percent. Protein should constitute 12 percent of your diet. If possible, take protein from legumes, like peas and beans. They're starchy and they contain carbohydrate. Some books call them supercarbohydrates. They are a very efficient form of nutrition. Take the balance of your diet from fats. The average 45% CHO diet is met by two servings from the dairy and protein group (each). Four servings from fruit/vegetable and grain groups (each) are taken. To increase CHO intake to 70% CHO, double your servings from fruit/vegetables and triple your servings from grains. See Figure 5-1.

Finally, rest the body. Try to get the maximum amount of rest you would normally take. Don't fight your body to get more rest than is normal for you. This only induces stress. As for unusual shoot schedules, try to shift your sleep times to accommodate them, but again, let your body's normal feelings be a guide in this. Forcing the issue doesn't work and only induces stress. There is a mild and natural technique to shifting day/night schedules that is discussed in the section on External physical contingencies (see jet lag).

MENTAL PREPARATION

Mental preparation, like physical preparation, should also be pursued as wholly as possible. It grows out of physical preparation and allows one to be ready in a way that is more total and complete. Mental preparation encompasses a galaxy of external and internal spheres. External

physical shoot requirements are the nuts and bolts of learning what you need to know and how to do what you have to do. External physical contingencies require anticipation and knowledge gained in studying peripheral aspects of a particular shoot. This is the "What's it like where I'm going, while I'm there?" part. Finally there are internal mental self requirements. Here, one cultivates and nurtures the seeds of positive attitude and grows high "confidence in success" levels. Here, one grows these plants tall and ingrains their roots deeply. Good farming...

External Physical Shoot Requirements

An obvious element of mental readiness is knowing about the shoot at hand. This is achieved through analysis, study, classroom and hands-on experience, as well as borrowed experiential learning. These make up the first of three aspects of mental preparation.

Analyze

Analyze the shoot and shoot requirements. What will you need to do to fulfill your part in completing the photographic assignment? What do you need to know to do these things? Talk to the DP. If it's appropriate (often not), ask questions of the director. The producer, assistant director, or production manager all might have answers to your questions.

Will new equipment be used? Does the new equipment require new techniques or procedures? Is there newer equipment to be suggested that can do the old jobs better? Are there new techniques that can do the same things better or faster? Can new techniques be developed by you that will take better advantage of new equipment or technologies (evolution) or enhance the power of older equipment and/or existing technologies? Is there old gear or techniques that you need to relearn? Could you benefit from a brushup or a small refresher?

Study

What can you do to satisfy the above contingencies? You can read. Some manufacturers publish equipment operating manuals for their products. Ask for these at technical bookstores. Also, small operating guides, in the form of one- to two-page "handouts," are made available on particular pieces of equipment. Contact the manufacturing company. Also, ask for these at camera rental houses. Specialized books are available on equipment and procedures. Books on equipment are most valuable if they are constantly updated. Procedural books can stay current longer. The three best books for assistants at the time of this writing are:

The American Cinematographer's Manual
Publisher: American Society of Cinematographers.
Good technical data.

Professional Cameraman's Handbook
By Sylvia Carlson with Verne Carlson
Publisher: Focal Press/Butterworth-Heinemann.
Excellent equipment operations manual with some treatment of peripheral gear.

The Camera Assistant's Manual
By David E. Elkins
Publisher: Focal Press/Butterworth-Heinemann.
Good general survey of job category. Good descriptive treatment of procedure.

Classroom/Hands-on Learning

Go get checked out on a particular piece of gear at a rental house or at the manufacturer. Often this can be done on the prep day. But, if it's a particularly complicated piece of gear, it's better to schedule a separate time ahead of the prep. This allows better learning at a more leisurely pace. Remember, a relaxed mental state is a more focused mental state. Retention is better. Also, questions might occur to you that might not if you are in a harried state at a big prep. Also, learning "day ahead" ensures your prep the next day will go smoother.

Borrowed Experiential Learning

This is simple. Pick a few brains. Talk to others who have had previous experience with similar shoots or unfamiliar techniques or have already used unknown pieces of equipment. This might include DPs, other assistants, key grips, and gaffers. Sometimes even directors, producers, or production managers may have the answers to your questions. Obviously, asking executives questions falls to a judgment call: how well do you know them and how informal is the relationship. Joe Sedelmeir will always be "on the phone, right now" or "in a meeting." Even if you say you're his brother-in-law. Especially then.

Dream

This is brainstorming. Take a space of quiet time, with no distractions, to just sit back, relax, achieve a daydream-like state, and think about the shoot. Look at the shoot as a whole. Imagine that you are holding the idea of the shoot, as an object, in your hands. Examine it. Turn it over and over. Look at it from different angles. Look at it as a whole and as pieces that make up the whole. Tinker. Pull it apart into major

components. Pull the large blocks apart. Digest the whole. This creative thinking process also works well in the analysis stage. It allows you to identify and target facets of the shoot that need attention. It will not only allow you to recognize the specific technical criteria of the shoot, but will also point to peripheral aspects of the job as a whole. This sphere is called...

External Physical Contingencies

This is everything else of a practical nature, outside the actual technical arena of the shoot. This is about getting ready for all the situations and circumstances that will happen to you before, during, and after the shoot, things that will affect you day and night, when you're awake and when you're asleep.

Where are you going? How far are you going? When are you going? What's it like there, then? Especially if you are traveling to a distant location, you should do a little research. Look at some books.

An atlas can tell you about geography, environment, elemental conditions (weather), and a little culture. The people are different; their customs are different. Where are the locals' heads at? What is the chief economy here? A people's basic approach to life often is a function of the bread and butter they put in their mouths; where they get it, how they get it. Are you going to a city, or will you be out in the country? What is the terrain like? Is it tundra, or is it mountains? What is the altitude? Will there possibly be altitude-related problems (dehydration, headaches, edema, etc.) to be dealt with? Maybe you'll be in a forest, dry desert, or dense jungle. Are you at sea level? Is there an ocean nearby? Are you on the water; on an island, maybe? What hemisphere? Going to the poles? Will you be at the equator? What time of year? Does June mean summer or winter? Weather and daylight cycles are a function of geographical location. This affects time zone; times you'll be working, times you must adjust to, day/night cycles you must adjust to, and scheduled work hours you must adjust to.

Weather

Weather is affected by everything. And weather affects everything from shooting schedules to the dampness of your socks. What season will it be when you're there? Common knowledge will tell you this. But an atlas will tell you average rain or snowfall for summer or winter. It will tell you average temperatures, as well as seasonal highs and lows. The percentage of sunny days is important to the emulsion choice and film order, as well as your sport bag.

What about nights? What percentage of your shoot is at night?

What are the nights like where you will be? How long are the nights at that time of year? While an atlas will tell you what they're like, other sources will tell you how long the nights last: when they start and when they end. How cold do they get?

There are a number of good sources for attaining local information, such as travel bookstores and libraries. Call the local weather service for a report of present weather and expected trends. Increase regularity of these calls as the shoot approaches, to get your own feel for the weather. A global weather number is currently available (as of this writing: dial 1-900-WEATHER. It describes weather conditions in roughly 900 locations around the world. A weather channel can be viewed on most cable systems.

Time Zone and Jet Lag

This involves more than just resetting your wristwatch. You must also reset your body clocks. How many thousands of miles away are you traveling? For each thousand miles you travel, your body is shifted, out of sync, ahead or behind by one full hour. This is why there are twenty-four hours in a day. During that period your body processes operate at different levels in regular cycles. These cycles are adapted to optimally fit your normal day/night schedule. These cycles are called circadian rhythms. By traveling through numerous time zones to a distant location and radically different time zone and accompanying day/night cycle, you have just given your circadian rhythms what is called a severe case of jet lag. You must re-synchronize your body cycles to a new set of waking/sleeping, working/resting schedules. There are ways to speed this process.

Jet lag is the desynchronization of your body's circadian rhythms, and modulation to varying degrees of non-naturally occurring phase difference, with each other and their own cycling schedules, according to the time of day. In plain English; your body clocks are all screwed up.

Jet lag does not like you. The sensation of jet lag is your body wanting to be somewhere else, at some other time—like where it just came from... now! Early symptoms include a developing sense of exhaustion. For a seven (hour) time zone change, the degree of severity will increase for approximately the next 12 hours. Peaking here, it will diminish to approximately 50 percent in the next six hours and repeat roughly the same cycle for up to 3 days, dipping to a 12 percent low and then climbing again to 50 percent of its original severity over the next 24 hours. This affects your concentration, memory, performance, your sense of time and place, and general sense of well-being.

Accompanying symptoms are disorientation, reduced physical abil-

ity, impaired mental acuity, confusion, inappropriate appetite and appetite loss, excretory and urinary schedule upset, and memory loss.

Then there are secondary symptoms: constipation, diarrhea, diminished libido, limited peripheral vision, decreased muscle tone, impaired night vision, reduced work capacity, slowed visual response times, reduced motor coordination, reduced reflex response time, pharmacological interaction, insomnia, continued acute fatigue, appetite loss, and headache. These all result from disrupted cyclic scheduling of body rhythms, thrown out of phase with each other and with the clock.

The mechanics of this affliction are complex. Simply, jet lag is precipitated by the inappropriate presentation of, and exposure to, otherwise normal (biochemically [internal], environmentally, and socioculturally) cues and stimuli. A symptom-similar affliction, called Seasonal Affective Disorder (SAD), occurs as the days shorten with the season. The cause of the disorder is believed to be related to diminished secretion of melatonin by the pineal gland. Normal discharge of this gland occurs in daytime, not at night. Exposure to bright light for 3 to 5 hours a day, simulating a 13-hour day, brings complete remission of all symptoms.

Internal desynchronization occurs in what are called "time-free environments." Shift work is an example. Normally linked physiorhythms go out of phase. Day sleep at cyclical body temperature maximums and night activity at cyclical temperature lows make for rest that is fitful, interrupted, and incomplete. Task performance is diminished in quality and rate by fatigue, which mars concentration as a result of collectively impaired mental faculty. Day activities that reinforce body clocks by day become genuine stressors to the body when shifted by one-quarter to one-half a day. You respond differently on a biochemical level, because you are biochemically a different person at 3:00 A.M. than you are at 8:30 P.M. Plants and animals have a natural chronobiological sense. In humans, each cell manufactures proteins, gene products, and other compounds on a preprogrammed schedule that takes "about a day" (circa dies) to run. The body senses the distinct differences between the middle of the night and early to mid evening.

Besides the self-stimulation of internal cues, external cues, acting as zeitgebers (time givers), also stimulate internal cues. When light strikes the eye, a neurotransmitter is released to the rest of the brain and in turn to the body. This signals the wakeful active phase to begin.

During the active phase, which is day for most humans, the body provides stimulants, which are the biochemical correlates of active behavior. The body produces the amino acids tyrosine, dihydroxyphenylalanine (L-dopa), dopamine, norepinephrine, and epinephrine. These natural chemicals stimulate the adrenergic pathways through-

out the brain and body. Stimulation of the catecholamine pathways ensures activity.

At night, when, long ago, activity could prove less adaptive, even fatal, the body discourages activity by production of another combination of chemicals. Adrenergic dominance declines as cholinergic processes excite indolamine pathways. Tryptophan and serotonin are produced in greater quantities. Stimulation of the indolamine pathway initiates a process that induces drowsiness and sleep.

Core temperature cycles regularly. Body temperature reaches its peak during the day. Temperature is lowest at night. This process is so fundamental to the body that temperature is considered a true sign of adaptation to a new day/night cycle.

Left undisturbed, the above processes occur naturally, cycling around a day that is approximately 25 hours long. Because of this natural tendency to phase-shift backward about an hour a day and the fact that we must reconcile our natural clock to a 24-hour sun cycle clock, it is fortunate that we can reset our body clocks slightly each day. We in fact do this every night, when we go to bed according to a 24-hour schedule. These natural cycles (our body clock) can be reset to a maximum of about 2 hours a day. This means that on a day-to-day basis (one day being 24 hours from the next) comfortable living within a 23- to 27-hour day is allowed by this parameter. This is why you can go to sleep and wake up a few hours later or earlier, quite comfortably, from one day to the next.

Body clocks determine body temperature, not the other way around. Yet the two are strong enough correlates that one may imply, or be inferred from, the other. At 12:00 midday (body time) body temperature is at its highest. At 12:00 midnight (body time), body temperature reaches its low, staying there through 3:00 A.M. to 4:00 A.M., with minor "spikes" around 5:00 A.M. The sleepiest time for the body is between 3:00 A.M. and 4:00 A.M.

These normal cycles determine when you want to be asleep and how long you want to be asleep. Sleep time depends on two factors: body time and sleep deprivation. If sleep is deprived, recovery sleep is of shorter duration in the A.M. (4 to 5 hours). Here, body temperature starts low, but it is rising. Recovery sleep is longer in the early P.M. (5 to 10 hours). Here, body temperature starts higher, but is falling to its low point. Sleep will be longest after body temperature has peaked and has begun to fall to its low point. This is a very useful "tidbit" if you are trying to rest up for a "night exterior."

The body's response to internal states, which also serve as internal cues, which are also a response to external cues and demands, is also a stimulus toward shifting the body's clocks. The body tries to adapt. It's

(the body's) such a wonderful thing. The degree and state of the body's adaptation, at any time during its course, alter the body's response to external and internal stimuli. Jet lag is a physical manifestation of stasis out of equilibrium. Stasis, like the hypothalamic feedback loop (the body's chief timing mechanism is believed to be centered there), exists in a circular relationship with itself. Thus, jet lag also exists in a circular relationship to the body and the external environment.

Jet lag is affected extrinsically and intrinsically. External cues and demands not only cause jet lag, they also cause jet lag to diminish. The body's response (internal states serve as internal cues) determines differing physical responses to the same external stimuli over (here's the key to it all) time. Ironic, isn't it? The changing response (desired response), or adaptation to a new schedule (external cues and demands) can be achieved in less time if we utilize the external cue → internal cue feedback system to our advantage. This means understanding the variables, externally and internally, that affect jet lag.

> External cue → internal cue → internal state → internal response → adaptation → external cue → internal cue occurring to body in adapted internal state causing different response to same external cue.

External cues that affect jet lag are light/dark cycles and eating and sleeping. Social cues are external cues also. They include mental stimulation, from intellectual activity like writing, reading, and work/study, and social stimulation, which comes from the kinds of socially oriented interpersonal interaction with others that occurs at work in the workplace. *Others* is key. Biosocial stimuli (eating with others) are important. This also increases exposure to new schedules, arranged to meet new activity/rest schedules.

Internal variables (acting chronobiologically) include chemicals that naturally occur in most people's everyday diet. Intoxicants affect jet lag. These compounds can measurably slow down or speed up body clocks. Much of their effect depends on the time of day. Coffee, tea, and chocolate contain caffeine, theophylline, and theobromine. These compounds fall into a category called methylated xanthines. Alcohol, nicotine, marijuana, and other drugs (pharmaceutical and nonpharmaceutical) affect body clocks. They can be disruptive to internal systems. Some can be used in a controlled manner to one's advantage in shifting body clocks.

The above variables that affect jet lag may be considered elective, in that one may choose, or deny oneself, exposure to them. One may also voluntarily regulate the time, duration, and degree of exposure. Some

variables one cannot control so readily. Age, day/night personality, and direction of travel are three factors that interact with jet lag to varying degrees. Older people show more severe jet lag. Night owls do better with jet lag than early birds. Direction of travel is the biggest variable affecting jet lag. A western destination and schedule are more easily adapted to than is an eastern destination and schedule. In westbound travel the day is extended. This is more in line with our body wanting to "free run" to a 25-hour day. Plus, you just have more time to adjust. The body is much more naturally inclined to go west.

An eastbound trip shortens your day. In a number of studies, eastbound travelers crossing six time zones have been shown to adapt by delaying physiological rhythms by up to 18 hours, rather than speeding the body by 6 hours. This is equivalent to adapting to a trip in a westerly direction over many more time zones. This demonstrates an important lesson that might prove of some value in managing one's own jet lag program. Though nothing can be done to change these nonelective variables, their assessment should figure into the extent of preparation for and practice of any jet lag (symptom-relief) program.

Remember not to fight the body. This only proves stressful. Remember that if the body cannot adjust to shorter days, it will "free run" its bio-clocks, drifting to later hours and longer days, until it can resynchronize to a new time zone. Now…how to speed the catching up resyncing process.

As we research resyncing we will be repeating certain subjects, but for different applications. Changing time zones is facilitated by the timed utilization of exercise, methylated xanthines, diet, and the manipulation of external natural and artificial variables. These are put together into a loosely regimented "program" and combined with a schedule of preferred waking, eating, and sleeping schedules.

Jet Lag Program

First, exercise. It helps shoot endurance and performance. And it's part of this program. Exercise can be used to manipulate glycogen levels. Glycogen levels are related to the effect of methylated xanthines (MZs) and other zeitgebers. Exercise also stimulates neurotransmitters that are associated with the active phase. Regular exercise promotes more stage-3 and stage-4 deep sleep. Infrequent exercise disturbs sleep patterns. The optimal time for exercise is early afternoon and evening. Use mild exercise on the plane during your destination active phase. It is also used before the timely use of MZs. This exercise program is a modified version of your regular program. Exercise has been shown to be a primary stimulus for increased glycogen synthesis. This is because exercise accomplishes the necessary lowering of glycogen stores. This

lowering is what leads to an opportunistic condition allowing "carbo loading" in individuals that are endurance trained. If you are not fit, the body can't take advantage of this enhanced storage mechanism. However, exercise can still be used to promote glycogen depletion.

Why is glycogen depletion important? It increases sensitivity to MZs, light/dark, and food as stimuli for shifting the body clock. Coffee, chocolate, and tea are foods that naturally contain the chemicals caffeine, theobromine, and theophylline. These compounds are called methylated xanthines. They seem to have an ability to reset body clocks, pushing them back or ahead, depending on the time of day they are reintroduced into the system. Cessation of their consumption for several days prior to their timely application is important. The body develops a tolerance to these chemicals. Abstinence increases sensitivity. Also, caffeine slows glycogen depletion. Remember glycogen depletion increases the body's sensitivity to the effects of MZs and other time-shifting stimuli.

We also need to control the body's reaction to the MZs. Their special effect is time dependent. MZs given in loosely controlled dosages show an ability to shift the body's main clock by a few hours. This shift may be forward or backward. It depends on the time of day these compounds are taken.

Ingested in the early morning, the effect is one of shifting the internal clock backward 2 to 3 hours. This would be an adjustment to a westerly time zone, creating a phase-shift delay. Here, the 24-hour cycle is delayed, compared to that in our time zone of origin. MZs administered in the evening have the effect of shifting internal clocks forward 2 to 3 hours. This would be an adjustment to an easterly time zone, creating a phase-shift advance. Here, the 24-hour cycle is advanced, compared to that in our time zone of origin.

Optimal effects are achieved through proper dosage, administered to the body in a maximally prepared state. This is achieved by promoting maximum sensitivity. This occurs at lowered body glycogen levels. Exercise maximizes this lowering. Refined carbohydrates (sugar as sweets: cookies, cakes, candy, and soda) taken before exercise increase the rate of glycogen metabolism (increase lowering). Fructose can be upsetting to the stomach during strenuous exercise. If your flight schedule overlaps with recommended coffee time (jet lag program) and your schedule precludes a full workout, avoid using sugar to augment glycogen metabolism. On a plane, you cannot exercise at 40 to 70% $V0_2$ MAX[1]. Only mild exercise, if any, is possible. Sugar taken could create a swamping insulin effect, negating any influence of the MZs contained in the coffee.

Approximately 330 mg caffeine are in 2 to 3 cups of coffee; 4 to 5

mg/kg (body weight) represents a pharmaceutical dose for the average-weight man (approximately 160 lbs). For a woman of 110 lbs, 1 to 2 cups of coffee provide this dosage. The actual concentration depends on the way the coffee is made—instant, percolated, drip, espresso, etc. Refer to Figure 5-4.

This program recommends a balanced diet based on a carbohydrate emphasis as opposed to alternating feast/fast regimens, stressing high protein content. The logic of a feast/fast regimen, founded on a high-protein diet, is aimed at promoting glycogen depletion, providing long-lasting energy during the day and inducing sleep at night with a meal high in carbohydrates. You ask, "What's wrong with that?" Well, the only thing wrong with that is that there are better ways to do the same thing.

Lower glycogen storage is achieved by this diet, but not to any greater degree than that attained by a balanced 48 percent carbohydrate diet. Also, the hard-to-digest protein emphasis during the day leaves the individual with a heavy, sleepy feeling after meals and a diminished reserve of the body's primary fuel source: carbohydrate. A high-protein diet is often a high fat diet, which is generally "not good" for most individuals. It is not the feast/fast that accomplishes the glycogen lowering, anyway. It's not the protein, it's the lack of carbohydrate. But protein is a poor fuel source of energy. Also, too much protein increases the body's need for water, used in the production of urea, to discharge excess nitrogen, a toxic by-product of protein metabolism. This seems to be at odds with most experts on jet lag, who suggest ample water consumption to combat dehydration, which is promoted by the "atmospheres" created in a pressurized airplane cabin.

Protein is not a primary energy source. Its chief role in the body is for tissue growth and repair. Protein is used as a fuel only when more efficient sources, such as carbohydrate and fat, are depleted. The body does not store proteins as such. They are broken down into amino acids, which are then recombined into proteins as they are needed. Amino acids are a source of aerobic fuel. They require a continuous supply of oxygen. This occurs only when the body state is elevated to an aerobic state. This occurs a few minutes after exercise, of low to moderate intensity, is initiated. A normal resting/working state is below this threshold. So, at an anaerobic state, protein is not even able to be used as a fuel source to provide energy.

A carbohydrate dinner as a stimulus for sleep has no strong empirical foundation. There is no strong body of evidence that protein stimulates adrenergic systems by day and carbohydrate stimulates indolamine pathways by night. "Diet and nutrition have little effect on sleep."[2] "There is little validation for any jet lag diet."[3]

Because feast/fast high-protein diets offer no real advantage, are possibly less than optimal for health and nutrition, and do not really support daily energy/rest requirements any more than other diets (and possibly to a lesser degree), I recommend the USDA-recommended balanced diet. This diet gets 48 percent of its calories from complex carbohydrates, and still allows appropriate glycogen depletion. This diet provides nutrition in a way that is most compatible with the body's energy utilization systems. Some researchers even feel that a slight modification of this diet promotes deeper sleep.

A balanced diet takes most of its calories from carbohydrate, the rest from protein and fat. For normal individuals (not endurance trained), 48 percent of their calories should come from complex carbohydrates, 8 to 12 percent from refined carbohydrates, 12 percent from protein, and 30 percent from fat. For those in heavy training, 60 percent should be carbohydrate, to avoid cumulative glycogen depletion. Training 3 to 5 hours/day requires a 70 percent carbohydrate diet to replace glycogen. So, for an individual exercising between 20 minutes and 1 hour, 3 to 5 days/week (minimum threshold endurance training), a 48 percent CHO diet still allows appropriate glycogen depletion, which enhances sensitivity to MZs and light/dark cycles.

A 48 percent CHO diet is most user friendly. Carbohydrate is the chief component, used by the body for glycogen synthesis. A carbohydrate diet is the most compatible with the body's primary form of energy metabolism. Carbohydrate is a primary fuel. Only carbohydrate can be used anaerobically, which is the body's basal, and often basic, state (below low to moderate exertion). CHO metabolism is inefficient, compared to its potential, used aerobically, but it is rapid. CHO provides energy for short bursts of exertion. CHO provides energy evenly for long-term expenditure.

Some researchers support the notion of a balanced diet's role in improved sleep. There has been some evidence that a balanced diet promotes deeper sleep. There are some claims that the amino acid L-tryptophan has sleep inducing properties. Eat a 48 percent CHO, balanced meal with a glass of milk. Have another glass about one-half hour before bed.

Alcohol affects internal clocks, possibly as much as do methylated xanthines and light/dark cycles. The effect is, at best, disruptive. I would avoid it during the transition period. But like everything, the call is yours.

Manipulation of natural and artificial variables has an effect on adapting to a new time zone. Manage your light exposure, reset your watch, use naps and practice activity/rest phases according to your destination.

Regulate your exposure to natural and artificial light and dark. Use light and dark to simulate time cycles at your destination. On the plane, lower your window shade during dark phases at your destination. Keep your light on during light phases according to your destination.

Reset your watch. Do this as soon as possible on the plane. Adjusting it while still at original location and still attending to responsibilities and obligations in a timely manner (like making your flight on time) could prove disastrous.

Taking naps while traveling west may help you to extend your day. Avoid them when traveling east, as they may interfere with advanced (earlier) sleep schedules.

Activity and rest should be regulated on the plane, as well as prior to your flight. Activity/rest phases should approach, as closely as possible, your destination schedule.

Finally, this is my own nontechnical approach to jet lag. It borrows from books and research on the topic. Everybody has a theory about something, so why can't I have one about jet lag? I feel the major determinants of internal clock stasis are related to the occurrence of regular biological functions that occur cyclically such that they are used as time cues by the body. In preparing to transition to a new time zone, to a degree, *what* you eat or *how long* you sleep may not be as important as *when* you eat and *when* you sleep. After all, timing will be the key issue where you are going, because it will be the chief difference where you are going. Add to this, intense light exposure. There is new research on this. Seek it out to increase your level of preparation. Dr. Charles Ehret is considered a pioneer in this field. His book is listed in the Bibliography. Good luck. Refer to the jet lag schedules (westbound and eastbound) that follow. All instructions are on an "if possible" basis. All meals are based on a 48 percent CHO diet.

Coffee ingestion is aimed at shifting clocks ahead or back. The suggested times depend on direction traveled and number of time zones compensated for, according to that day's rise time. Here's an example: If, one day before an eastbound trip to a destination two time zones away, you have adjusted your rise time by getting up two hours earlier, your body has compensated for two time zones by adjusting its clocks by two hours. If suggested coffee time is 5:00 P.M./4:00 P.M., you would take coffee at 4:00 P.M. If you are traveling to a destination only one time zone away and have adjusted your rise time by one hour, you would take coffee at 5:00 P.M. For eastbound traveling: the more time zones east you enter (and need to compensate your body clock for), the earlier is your choice of coffee time (fewer time zones east [5:00 P.M.]/more time zones east [4:00 P.M.]). Westbound suggested coffee times are not as strict. West is easier.

Westbound: 1–2 hours

Preflight
2 days before flight day:
stop MZs
1 day before:
meals, bed—1 to 2 hours later
2 to 3 cups black coffee between 8:00 A.M. and 12 noon or 9:00 A.M. and 1:00 P.M. only (shifts internal time earlier)
no alcohol

Flight day
Day of flight:
rise and meals—1 to 2 hours later
sugar before exercise
exercise before coffee
2 to 3 cups black coffee by 12:00 noon or 1:00 P.M. only
On plane:
reset watch
no alcohol today
water for dehydration
nap OK

Destination
meals, bed—on time zone
snacks after supper OK

Next day
rise—on time zone
sugar → exercise (body/mind) → breakfast
MZs OK
alcohol OK
snacks after supper OK

Westbound: 3–4 hours

Preflight
3 days before:
stop MZs
2 days before:
rise, meals, bed—1 to 2 hours later if possible
same restrictions
1 day before:
rise, meals, bed—2 to 3 hours later if possible

2 to 3 cups black coffee between 9:00 A.M. and 1:00 P.M., or 10:00 A.M. and 2:00 P.M., only
no alcohol

Flight day
Day of:
rise, meals, bed—3 to 4 hours later if possible
sugar before exercise
exercise before coffee
2 to 3 cups black coffee by 2:30 P.M. or 3:30 P.M. only
On plane:
reset watch
no alcohol today
water for dehydration
nap

Destination
meals, bed—on time zone
snacks after supper OK

Next day
rise—on time zone
sugar → exercise body/mind → breakfast
snacks after supper OK
MZs OK
alcohol OK

Westbound: 5-6 hours

Preflight
5 days before:
rise, meals, bed—1 to 2 hours later
stop MZs
snacks after supper OK
4 days before:
rise, meals, bed—2 to 3 hours later
same instructions
3 days before:
rise, meals, bed—3 to 4 hours later
same instructions
2 days before:
same instructions
1 day before:
same instructions

Flight day

Day of:

meals, rise—4 to 5 hours later

sugar before exercise

exercise before coffee

2 to 3 cups black coffee between 11:00 A.M. and 3:00 P.M. or 12 noon and 4:00 P.M. only

On plane:

reset watch

no alcohol today

water for dehydration

nap

Destination

meals—bed on time zone

snacks after supper OK

Next day

rise on time zone

sugar → exercise body/mind → breakfast

no MZs (MZs 2nd day post arrival/5–6-hour time change)

no alcohol (alcohol allowed same as MZs)

Westbound: 7–8 hours

Preflight

7 days before:

rise, meals, bed—1 to 2 hours later

stop MZs

snacks after supper OK

6 days before:

rise, meals, bed—2 to 3 hours later

same instructions

5 days before:

rise, meals, bed—3 to 4 hours later

same instructions

4 days before:

rise, meals, bed—4 to 5 hours later

same instructions

3 days before:

same instructions

2 days before:

rise, meals, bed—5 to 6 hours later

same instructions

1 day before:
rise, meals, bed—6 to 7 hours later
same instructions

Flight day:
Day of:
rise, meals bed—6 to 7 hours later
sugar before exercise
exercise before coffee
2 to 3 cups black coffee between 1:00 P.M. and 5:30 P.M. or 2:00 P.M. and 6:30 P.M., only
On plane:
reset watch
no alcohol today
water for dehydration
nap

Destination
meals—bed on time zone
snacks after supper OK

Next day
rise—on new time zone
sugar → exercise body/mind → breakfast
no MZs (MZs 3rd day post arrival/7–8-hour time change)
no alcohol (alcohol allowed same as MZs)

Westbound: 9–10 hours

Preflight
9 days before:
rise, meals, bed—1 to 2 hours later
stop MZs
snacks after supper OK
8 days before:
rise, meals, bed—2 to 3 hours later
same instructions
7 days before:
rise, meals, bed—3 to 4 hours later
same instructions
6 days before:
rise, meals, bed—4 to 5 hours later
same instructions

5 days before:
same instructions
4 days before:
rise, meals, bed—5 to 6 hours later
same instructions
3 days before:
same instructions
2 days before:
rise, meals, bed—6 to 7 hours later
same instructions
1 day before:
same instructions

Flight day
Day of:
rise, meals, bed—7 to 8 hours later
on rising: sugar → exercise → breakfast/coffee
2 to 3 cups black coffee immediately after exercise only
On plane:
reset watch
no alcohol today
water for dehydration
nap

Destination
meals—bed on time zone
snacks after supper OK

Next day
rise—on new time zone
sugar → exercise body/mind → breakfast
no MZs (MZs 4th day post arrival/9–10-hour time change)
no alcohol (alcohol allowed same as MZs)

Eastbound: 1–2 hours

Preflight
2 days before:
rise, meals, bed—1 to 2 hours earlier
stop MZs
no snacks after supper
1 day before:
rise, meals, bed—1 to 2 hours earlier
2 to 3 cups black coffee only at 5:00 P.M./4:00 P.M. (origin time—see text)
no alcohol

Flight day

Day of:

rise, meals, bed—1 to 2 hours earlier
sugar before exercise
exercise before breakfast (no MZs)
no MZs today

On plane

reset watch
no alcohol today
water for dehydration
no nap

Destination:

meals, bed, rise—on time zone
sugar → exercise → breakfast (no MZs)
no snacks after supper

Next day

rise, meals, bed—on time zone
MZs OK
alcohol OK

Eastbound: 3-4 hours

Preflight

3 days before:

rise, meals, bed—1 to 2 hours earlier
stop MZs
no snacks after supper

2 days before:

rise, meals, bed—2 to 3 hours earlier
same instructions

1 day before:

same instructions

Flight day

Day of:

rise, meals, bed; 3 to 4 hours earlier
sugar before exercise
exercise before breakfast (no MZs)
2 to 3 cups black coffee at 3:00 P.M./2:00 P.M. (origin time—see text)

On plane:

reset watch
no alcohol today
water for dehydration

no snacks after supper
no naps (unless flying at destination bedtime)

Destination
meals, bed—on time zone
breakfast—*destination time* (24 hours post-flight day morning):
sugar → exercise → breakfast (no MZs)
no alcohol

Next day
rise, meals, bed—on time zone
MZs OK
alcohol OK

Eastbound: 5-6 hours

Preflight
5 days before:
rise, meals, bed—1 to 2 hours earlier
stop MZs
no snacks after supper
4 days before:
rise, meals, bed—2 to 3 hours earlier
same instructions
3 days before:
rise, meals, bed—3 to 4 hours earlier
sugar before exercise
exercise before breakfast (no MZs)
same instructions
2 days before:
same instructions
1 day before:
rise, meals, bed—4 to 5 hours earlier
same instructions

Flight day
Day of:
rise, meals, bed—5 to 6 hours earlier
sugar before exercise
exercise before breakfast (no MZs)
2 to 3 cups black coffee at 1:00 P.M./12 noon (see text)
On plane:
reset watch
no alcohol today
water for dehydration

no snacks after supper
no naps (unless flying at destination bedtime)

Destination
meals, bed—on time zone
breakfast—*destination time* (24 hours post-flight day morning):
sugar → breakfast → breakfast (no MZs)
no alcohol

Next day
rise, meals, bed–on time zone
sugar → exercise body/mind → breakfast
no MZs (MZs 2nd day post arrival/5–6-hour time change)
no alcohol (alcohol allowed same as MZs)

Eastbound: 7–8 hours

Preflight
7 days before:
rise, meals, bed—1 to 2 hours earlier
stop MZs
6 days before:
rise, meals, bed—2 to 3 hours earlier
same instructions
5 days before:
rise, meals, bed—3 to 4 hours earlier
same instructions
4 days before:
rise, meals, bed—4 to 5 hours earlier
same instructions
3 days before:
rise, meals, bed—5 to 6 hours earlier
same instructions
2 days before:
same instructions
1 day before:
rise, meals, bed—6 to 7 hours earlier
same instructions

Flight day
Day of:
rise, meals, bed—6 to 7 hours earlier
sugar before exercise
exercise before breakfast (no MZs)
2 to 3 cups black coffee at 12 noon/11:00 A.M. (see text)

On plane:
reset watch
no alcohol today
water for dehydration
no snacks after supper
no naps (unless flying at destination bedtime)

Destination
meals, bed—on time zone
breakfast—*destination time* (24 hours post-flight day morning):
sugar → exercise → breakfast
1 to 2 cups black coffee between 6:00 A.M. to 7:30 A.M., only (24 hours post-flight day morning)
no alcohol

Next day
rise, meals, bed—on time zone
no MZs (MZs 3rd day post arrival/7–8-hour time change)
no alcohol today (resume alcohol same as normal use of MZs)

Eastbound: 9–10 hours

Preflight
9 days before:
rise, meals, bed—1 to 2 hours earlier
stop MZs
8 days before:
rise, meals, bed—2 to 3 hours earlier
same instructions
7 days before:
rise, meals, bed—3 to 4 hours earlier
same instructions
6 days before:
rise, meals, bed—4 to 5 hours earlier
same instructions
5 days before:
same instructions
4 days before:
rise, meals, bed—5 to 6 hours earlier
3 days before:
same instructions
2 days before:
rise, meals, bed—6 to 7 hours earlier
1 day before:
same instructions

Flight day

Day of:

rise, meals, bed—7 to 8 hours earlier

sugar before exercise

exercise before breakfast (no MZs)

On plane:

reset watch

no alcohol

water for dehydration

no snacks after supper

no naps (unless flying at destination bedtime)

Destination

meals, bed, rise—on time zone

breakfast—*destination time* (24 hours post-flight day morning):

sugar → exercise → breakfast

2 to 3 cups black coffee by 9:30 A.M., only

no naps

no alcohol

Next day

rise, meals, bed—on time zone

no MZs (MZs 4th day post arrival/9–10-hour time change)

no alcohol today (resume alcohol same as normal use of MZs)

East/West: 11–12 hours

Preflight

11 days before:

rise, meals, bed—1 to 2 hours ahead/behind

no MZs

10 days before:

rise, meals, bed—2 to 3 hours ahead/behind

same instructions

9 days before:

rise, meals, bed—3 to 4 hours ahead/behind

same instructions

8 days before:

rise, meals, bed—4 to 5 hours ahead/behind

same instructions

7 days before:

same instructions

6 days before:

rise, meals, bed—5 to 6 hours ahead/behind

same instructions

Appreciate the positive. Realize your own effort in this endeavor of self. Appreciate it and give yourself credit for trying to improve. Know that those who try to improve most often do (most). Visualize others appreciating your success and prowess. Everyone values improvement, especially bosses. It sounds hokey, but this stuff works. Try it.

This is total preparation. It seems like a lot, but with planning, most of it should fall into place quite naturally, with no great extra pressure on your time. You may elect to follow some or all of it, as the real world allows. The package is prepared. Deliver it!

DELIVER: THE FIRST LAW OF FREELANCING

Deliver! This is what the first law of freelancing is all about. The first law of freelancing states, The answer to every question is yes; best followed by, "Yeah, sure. No problem. Done it a thousand times. Piece o' cake. Watch this." In short, deliver! This is what a freelancer does. Successful completion of this implicit task allows a freelancer to succeed, to pay his bills, to make his living, to be what he is and not a computer salesman or an insurance adjuster. What is a freelancer? A freelancer is one who freelances.

Webster's New World Dictionary defines "freelance" as "a writer, actor, etc., who is not under contract for regular work, but sells his writings or services to any buyer."

The key word here is "any." *Any* buyer may ask for *any*thing. Because "any" implies many different buyers, infer that many different buyers will ask for many different things. A freelancer's task is to provide for these various requests, covering a spectrum that is virtually unlimited in kind and combination of elements. Every job is different. One thing remains the same: *You must deliver!*

Today is the day of the shoot. This is where everything comes together. In total preparation, you are technically, mentally, and personally ready. You have prepared technically the camera and your tools. You have prepared physically your personal gear, exercised your body, and specialized its diet. You have prepared mentally, examining external physical shoot requirements and external physical contingencies. You have met internal mental self requirements and have cultivated a rich Zen inner state. You are prepared even to expect the unexpected. You are ready. This preparedness lends you a state of enhanced assuredness and calm. In the wake of this total calm is mental quiet, an opening blank space in which the mind is totally free to focus and concentrate. This will provide the power of every action this day. Before and during every action is thought; enhanced thought that will enhance your precision and effectiveness in everything you do, every move you

make. The result is everything you do and don't do is better because everything is well thought out. Everything is for a reason. Economy of effort. Strip down and gear up. Let's Zen through a non-extreme day.

We know it's not a perfect world. Rise after eight hours or preferred rest time. Allow plenty of time. Some shower and leave. Some eat and relax. You will obviously do what works for you. Out the door: run through a mental checklist: batteries, film and/or mags, kit, sport bag, shoot papers and info, extras. Allow plenty of time. Stressing over being late is an awful way to start the day.

Arrive. Try to get the truck parked in shade for the hottest part of the day, or sunlight for the coldest part of the day. Stow your gear and go say hi. Or jump right in and say your hellos later. Reach a good point. The camera is built and to the set. People (2nd assistant and loader) are organized (talked to), gear, carts, and kit bag are organized.

Idle. Get a little coffee, juice, and/or food. Prepare sunscreen, glasses, etc. Think about the shoot day and the first shot. Talk to the DP if he's in a good "idling" stage. Are there any changes? Any last-minute good ideas? Walk (measure) set, scope out the shot. Visualize the whole thing (generally and specifically). If the shot is hard, keep mentally preparing right up until it's time to roll. If not, stand by ready, relaxed, idling.

Shoot out the first shot, break setup, repeat setup routine, keep shooting to midmorning. If it's very hot, you should already be drinking extra fluids even if you're not feeling thirsty. Fruit is good food, because there's water in it. It doesn't take extra water to digest like proteins do; it's a carbohydrate and it leaves no after-lag, as do a lot of other foods that are on the food table. Orange juice is food in an excellent form. It's fluid. The fructose is a good form of sugar. It's carbohydrate and you can consume it quickly. Refined carbohydrates like sugary sweets can work either way (see diet text). Lox (fish) are excellent nutrition, but can feel a little heavy. Eating them as plain as possible is the best and also the least fun. Meats and cheeses are fun, but will leave you feeling heavy. There's nothing really wrong with anything you don't have a problem with.

Continue shooting until lunch. Try to gauge film use for the rest of the afternoon. Think about stock changes and preparing mags for failing light. At lunch, leave any big changes until after you come back, if time will allow. This is because the mental and physical effort entailed will "warm you up" again. The after-lunch drags are often completely cleared up after a significant camera "restart." Save film changes, battery changes, and moves for this reason. Again, this is providing time allows.

If you eat now, eating lighter is more comfortable. Some guys can eat a huge "hot meal" and feel as fresh as they ever do. If this isn't you, light CHO is best: salad, vegetables, potatoes, bread, and rice. Of the

meats, fish is best, then chicken, then red meat (which will make you feel the sleepiest). Fruit for dessert will avoid adding a sleepy feeling. If you really want to have the fun stuff, make a plate of everything you want, cover it, and put it on the truck. Eat light now and scarf on the big plate later in the afternoon, after your metabolism begins to climb again. Or, don't eat at all now, if it's not your time. Make a plate for later. For some, this independent behavior does something that can only be explained as psychological, but the effect is real.

Try to finish lunch a few minutes early and get away. A short meditative, quiet time is beneficial. A few minutes of quiet reading leaves a noticeably fresh feeling. This is different from talking. But most important, do what you want to do—this will probably be most refreshing. If you're having a good time talking at lunch with your friends, stay there and enjoy yourself.

Back at the camera, restart your crew. Get film, battery, and major camera changes done. Make the big camera move. Carry it yourself; your sleepy body will be glad you did. We're talking heart rate and circulation. Coffee works as a jump start here.

Shoot out the afternoon. Anticipate light failing and film stock changes. Prepare for the "dying light dance of death." Keep an extra battery and mag close by. Wrap. Say good night.

This may seem like a lame, obvious section at first. It's meant to be general. We've gone over the specifics. You should know how to apply them. Now, some general comments about this general day description.

The point is not to trick (sabotage) yourself. Get enough rest. Give yourself time to get out the door and get to work comfortably. The pressure will start soon enough and a relaxed mind concentrates better in a storm.

Be organized and prepared. Know where you're going to work. Know how to get there and how long it will take. You should be in this position by the night before. Look at maps and call sheets the day before. Don't make it stress time in the morning, or surprise yourself with just how far away the location really is.

And try to have an idea of what you are going to be doing once you get there. Even go over the camera build in your mind once, on your way there, especially if the startup is at all tricky. Doing this kind of thing allows you to always have a bit of your own direction, even when the company is floundering.

Don't kill yourself with all the great food they heap on those tables. I know, I love it too. But use the huge choice to help your body and frame of mind.

Remember what you know about extreme conditions: hot, cold, exposure, hydration, and diet. Put the truck in the best place for you, the

gear, and the weather. In cold, make sure your layers are fresh, dry, and sweat free. In heat, actively seek shade. If the camera's in sunlight and you don't need to be next to it, shade it and the batteries and deliberately seek shade for yourself. Sit down in it, spending less energy than standing and move as little as possible. If given conscious thought, movement and energy waste in exertion and cooling can be greatly reduced.

Don't waste energy "trying" to rest. Sit only if you can remain sitting for a period of time. It's better to stand for a long period than to sit for many short periods. Getting up and down frequently wastes great amounts of energy and heats the body unnecessarily.

Get good at the heat. Learn to enjoy the heat and all the things that come with it. This includes what some people (even you) might usually consider uncomfortable. It's all a mind-set. Have your sport bag geared to cool. Spray iced Sea Breeze on exposed body parts. Drape towels over your neck that have been soaked in iced H_2O/Sea Breeze buckets. Keep a dry towel to wipe surface grime off the skin. This eases sweating, allowing heat radiation. Enjoy pouring water over your head. Don't worry about your clothes. Become animal-like in the heat.

Hydrate. Drink massive quantities of cold water long before you feel any thirst. By the time you feel thirsty, it's too late and you're already way behind. At this stage even your mental performance can be impaired, no kidding.

Don't trick yourself mentally. Don't hypnotize yourself into feeling to a greater degree the heat or the cold. You see some people dragging around and hear them say, "I'm so hot" or, "It's so hot out..." They've convinced themselves right into a draggy state.

Be smart in the cold. Have your sport bag geared to the cold. Don't overdress. If you get too hot and sweat heavily, the insulation qualities of your clothes is greatly reduced. Remove layers if you get warm. Add layers if you get cold. Use heat packs. Keep your feet warm and dry. Change into extra socks, if you need to. Cold ground or a cement floor can chill your whole body.

Enjoy the cold and your conquering of it. Park trucks in the sun. Provide warmth for your batteries. Keep lenses at shooting temperature starting 12 hours before. Avoid shocky temperature changes for your body too. Avoid going in and out of hot environments. Don't pop into a trailer for a quick warmup. Conserve movement. Avoid unnecessary trips around the set.

One final note about working at night (dusk 'til dawn). Take extra vitamins 12 hours before the shoot. Take the normal amount of vitamins, at the normal time, on the morning of the shoot. At the beginning of the night, take another normal dosage. If you use caffeine to

stay awake, don't start early or you'll have no sensitivity to it later, when you really need it. Ginseng tea is an herb tea that is extremely effective. It contains panax ginseng, which has a noticeable effect on freshness. It gives a less harsh feeling than caffeine. Use this tea first and try not to use coffee. If you really need to get out the big guns, "go for the Joe," but you'll find that, at a really late hour, if the tea works for you it leaves you feeling much better than the coffee does.

Being prepared, being smart, and using common sense take thought. Using thought helps ensure success in comfort, relaxation, concentration, and performance. Do well; be happy; do well. Deliver!

DEALING WITH FAILURE: WHAT TO DO WHEN YOU CAN'T WIN

"You're fired!" You're fired because of...

lack of ability
too slow
too sloppy
bad conduct
bad luck (bad circumstances and coincidences—it happens)
bad attitude
boss doesn't like you (this is usually tagged bad attitude)

You can be fired for any of the above reasons. If you just fell victim to some bad luck of whatever nature, this will not have been seen by the boss, or you wouldn't have been fired. This is if he's a fair boss. You can have bad luck; have the boss know about it, understand it or not, and still he'll fire you. You can have a cowardly boss who knows you're not at fault, who'll still fire you to cover his own butt. This is indeed bad luck. The truth, of course, will not be seen and/or admitted by your boss. If he just doesn't like you, this too is indeed bad luck, and this too will not be admitted by your boss. The reason will be euphemized into something akin to and mysterious as "bad vibes." Just what are "bad vibes" anyway? Are they like what country doctors, one hundred years ago, used to refer to as "the vapors"? No. Bad vibes are a result of someone projecting his own negativism onto some usually innocent other. Anyway, you can bet this "tragic magic" on the boss's part will be turned onto you and tagged as your problem. Here, the one projecting bad feelings onto you can escape taking any responsibility and avoid dealing, in a mature manner, with a bad situation or his own

inadequacies. The notorious first cousin of bad vibes is that good old unemployment dart called "bad attitude."

This dart tends to pop a lot of other bubbles too. It deflates egos, lowers self-esteem, and can flatten a good, healthy sense of self and self-worth. The potential damage done by this loosely wielded bludgeon far outweighs any motivational value it might have toward self-correction and improvement. The negative results of this kind of ego damage translate into impaired performance and use of personal and technical skills in that all-important arena called "next time."

Get ready for next time. Forget about spilled milk. Let your old boss clean it up. If he fired you for some bogus reason, which is often the case, his clothes are soaked in the mess and he'll never get the sour smell off him. Everybody pays his own price.

This is moving on. To move on is to have no time to wallow in the folly of one's self-importance. Do you think your failures matter enough that you should let them change the future? Who the hell do you think you are? A warrior is impeccable. To be that way he has no time to close up in defense and let his own death take him quietly. This is what Don Juan would say.[4]

Impeccability is what Robert DeNiro strove for and sometimes represented in *The Deer Hunter.* On a trip with his blundering, beer drinkin' buddies, one of them loses his hunting boots and asks to borrow a pair from DeNiro. (Of course he has extra. He's prepared. He's impeccable. And it's the movies, and his character has to be that way.) Anyway, at his buddy's request, DeNiro is astounded and angered at this fumbling boob, who doesn't have enough personal power to hang onto his shoes. He surely doesn't deserve to put himself above the life of a beautiful and impeccable wild stag. DeNiro rails to his buddy about being impeccable. He waves a rifle bullet in his friend's face and shouts, "See this? This is this! It ain't nothin' else. It's this!" He jams it into the rifle and slams shut the bolt. Do you understand the message of simplicity, perfection, pureness of purpose, and creativity of intent?

Do not be distracted by fools. There's a whole zoo full of them out there, especially in Los Angeles. When you buy into the load of beans they're trying to sell you, you give up your power to them. And they can't use it anyway. What a waste.

Take your own honest analysis of the situation and act on it. Recognize faults and correct them. Improve shortcomings. Admit your mistakes. Also, recognize when you are being shanghaied and never confuse the two. However, if you think it's them when it's you, then you're the fool. Don't be a monkey; they can't ride horses.

Get back on. Unfortunately there can be carryover into tentative performance in interviews, timidity in risk taking (rule breaking for

advanced assistants) and interpersonal interaction with boss types. All these occurrences can hurt you. You must leave behind emotional deadwood. Try to intellectualize it away and hopefully your convictions will become heartfelt, where they count. Diminish their (failures') importance.

Look at the real world. Everyone's been fired at least once. This includes people who are "very good." You have worked before and have done well. You will do well again. Or did this event magically change you into someone else, who is bad at what he does, has no experience, and is devoid of technical knowledge? Of course it didn't. You're still you.

Use memory, self-hypnosis, suggestion, or relaxed visualization to reinforce your positive self-image. Recall past highpoints. Visualize old and future wins. Take good care of yourself. Prepare and go do another job. It'll probably be years before you're fired again. Hah! Someone who tried to badmouth me off a job by telling (true) stories to a producer friend of mine was reminded by that same producer of the time that same someone was dragged off a stage by FBI agents. Lesson? Nobody's perfect. There are a lot of horse's asses out there, and if you stand here long enough, you *will* get crushed, 'cause somebody's gonna try and sit on you. That's just the way it is. Get up and walk away.

CAMERAMAN MYSTIQUE

Dismiss the myth of the "cameraman mystique." You're just an assistant; you don't deserve to stand under this umbrella, anyway. This section is mostly for those who are new. Experienced assistants should know this. It's all garbage.

The misguided notion that the camera department is somehow above the grips and electricians is naive. Believing this is the true mark of an outsider. How foolish to make so many assumptions based on a pair of clean hands.

So much is misinterpreted. People see grips and gaffers doing heavy work in dirty clothes with dirty hands. People see them use simple gear and assume simple minds. They see a large group of workers as a tribe of "good ol' boys." They assume each member of a larger group individually has less power. They see their deference to "Camera" as a form of submissiveness and subservience. They see the assistant standing near the higher end of the chain of command and assume he occupies a higher place on the evolutionary ladder. People see grips and gaffers standing around. Assistants get to sit. (That's to keep them out of the way where they will not hurt themselves or anybody or any-

thing else. It's like what an adult does with a small child. Often an assistant is offered a seat because his head's in the gaffer's eyelight.)

The outsiders who make hasty judgments out of context are truly ignorant natives peering through the bushes at something they don't understand. People see assistants with clean hands. They see assistants with clean clothes (sometimes). People see assistants with high-tech-looking gear. People see assistants with movie cameras. People see assistants alone or in small groups. They assume this means they have more power. The secrets shared only by a few must be more precious. People don't see them constantly walking up to and deferring to the DP. That's because, as assistants, they're always standing right next to the DP. People see the assistant standing in the deference line of fire and misinterpret it. People see assistants sitting down and being offered places to sit and things to sit down on. That's because they want the assistant to be able to concentrate, so he can get his focus and/or zoom right and they can all go home sooner.

People don't see at all. This is what's true. The difference between a DP and an assistant is like the difference between a doctor and a nurse in level of training, knowledge, and pay. What's the difference between a highlight and a flare? Day rate. An assistant is a department head, just like the key grip and the gaffer. He makes the same rate of pay. Assistants ride on dollies because they're too stupid to walk and chew gum (pull focus). Don't do this. Walk as much as you can, unless it's just an absolute impossibility. And if you have to ride, get off for the return trip and help push the dolly back to the other end of the track. If you're going to ride, ride for rehearsals too. This is for the dolly grip. He needs to get used to your weight so he can know how to compensate for it and incorporate this into his move. These guys are artists. A beautiful dolly move is a beautiful camera move if the operator can hold up his end. (Some idiots can't and try to blame the dolly grip. This is horse puckey.) This is the best way an operator can try to sabotage himself. Being a professional, the grip will not let his feelings get in the way of his work. Assistants can shoot themselves in the foot in ways similar to a jerky operator. Don't do it. A good dolly grip is worth his weight in gold. Ask any good operator or assistant.

What else is true: assistants have clean clothes because they can (most of the time). A movie camera looks "neat" (cute), but it's a fairly simple piece of hardware that hasn't changed much since the forties. Literally less than a handful of different models are in common use, and their controls are always in the same place. Here, there are no problems to solve, only technical procedures to follow by rote, like a monkey. Same damn routine, every damn time.

Let's compare two pieces of equipment from two departments

(camera and grip). Let's use this as a means of comparing technical and creative criteria involved in each. Let's compare a movie camera to a "C-stand." A comprehensive motion picture camera system costs around a quarter of a million dollars. A C-stand costs $134. Both are overpriced and would cost considerably less if more were manufactured.

But the movie biz is a small economy being sucked dry by small people. A movie camera is made up of about four thousand parts, a C-stand roughly twenty. A movie camera, built into even a minimal shooting configuration, breaks down into six to ten cases. A C-stand doesn't even come in a case, and it stands as a single unit. Four to six, even more, can be carried in the arms of the right-sized grip. A C-stand, with its two articulated joints, is capable of literally an infinite number of configurations. It allows placement of whatever can be attached to it literally anywhere in three-dimensional space. It takes a creative mind to take full advantage of this seemingly simple instrument's limitless potential.

Engineers and experimental and theoretical scientists talk about the concept of elegant simplicity. To this end, a C-stand is elegantly impeccable and impeccably elegant. A Taoist would like a C-stand. It's like directing. Anybody can say "action" and "cut," but the difference in what happens between these two words is what separates the men from the boys, or the geniuses from the "technicians" (mediocre directors).

Next to the immense power in potential of this simple instrument, a movie camera pales in comparison. A movie camera is a limited piece of hardware, capable of only a few restricted operating modes that never change. Don't misunderstand. It would not be Taoist or Zen to consider these comments as negative. I'm merely comparing the two. A key concept in this comparison is the word *hardware*. Let's compare it to software.

Software, as in creative thought and problem solving, is the true power in any system. Hardware is the necessary support required to yield the end product that springs from a creative seed. A camera is hardware. Grips and gaffers, like the DP, are problem solvers. Every day, every shot is different. Every Arriflex, Panavision, Mitchell, Eclair, and so on is just like every other Arriflex, Panavision, Mitchell, Eclair, etc. And every button is in the same place.

Are you just a glorified button monkey? In some ways, yes. Have I overstated the case? Definitely, yes. But I've made a point well needed to be made. Don't make the naive mistake of being overly impressed with yourself and your clean clothes.

Give the prima donna routine a rest. Being a prima donna is bad enough, but trying to be one when you haven't achieved a high enough station is misfounded self-pride and an attempt at the abuse of power one doesn't even have. Forget it.

THE LAST GASP—MYSTICISM AND THE ZEN OF WORK

This is the conclusion of this book. I'm not going to recap. If you want to know again what you read, go look in the table of contents. Instead, just a few parting thoughts.

First, don't take it all too seriously. It's all horse stuff. You'll make a fool of yourself. Actually, making a fool of oneself isn't such a bad thing. But a lot of us don't like to do it. Being too concerned with never appearing a fool is to be overly concerned with one's safety of self-image and the image one presents to others. This in itself is foolish. Don Juan calls it folly. It is also self-limiting, which is the opposite of what this book has been about. To be too careful precludes the possibility of taking risks and chances. This is where one can go beyond and grow beyond. It is to push the outer edge of the envelope. Here, you may soar. If you crash, you will at least go down in a blaze of glory (impeccability). You will have gone much farther than those timid, safe few who merely exist (subsist) on the same mediocre level forever. In this case a truly great word like "forever" is truly unremarkable. So don't take anything too seriously—one's self, one's self-image, one's safety, one's importance, one's job. It's only your job, not your life. Film students and first-day employees don't understand this. They'll learn, God help 'em. By the way, once you do understand this, never admit it. Now do you see why it's all horse stuff?

Second, if you're just considering this profession, don't. Go into accounting, medicine, law, better yet, pro sports. Or become an actor and direct. That's where the real power is. You can even be president one day, if you want to take a step down in the eyes of much of the world. But you maybe have spent some time as an assistant and are getting old to compete with college-age graduates in other professions. Your eligibility and "trainability" in the eyes of some is declining. You may be stuck here for now, which isn't very Zen. But if you are "stuck," according to yourself, make the most of it. This is Zen. This book is about that.

Now there's nothing really special about this book. Most assistants who have been practicing their craft for a while have discovered for themselves many, if not all, of the concepts and techniques contained here. This book is unique in that it's the first attempt to organize the foregoing into a body of knowledge, with application intended primarily for assistant cameramen. I'd like to say *especially* for assistants, to introduce the word "special." Many fields have built up whole organizational infrastructures not directly aimed at the execution of their primary task, but at the enhancement of the execution of the primary task. Business is very big in this. Filmmaking has not basically changed since the early part of the century. So there is room for filmmakers to

tios change, as well. The first three ratios are called sine of angle theta, cosine of angle theta, and tangent of angle theta, respectively. The second three—cosecant, secant, and cotangent—are reciprocals of the first three. This book will discuss only the first three and it uses only the tangent function.

Sine angle theta = a/c = opposite side/hypotenuse
Cosine angle theta = b/c = adjacent side/hypotenuse
Tangent angle theta = a/b = opposite side/adjacent side

In a right triangle, as the value or size of angle theta changes, so does the value of one or both legs making up the ratio. The size of the angle dictates the value of the ratio. These ratios can be used to find angle sizes for vertex angles (sighting angles) for selected distances. The ratios can also be used to find angular span for sighting triangles.

The relationship of the internal angles of a triangle from 0° to 89° 59′ can be found in the trigonometric tables appropriate to natural sines, natural cosines or natural tangents. See the trigonometric tables in the appendix at the end of this book.

HOW TO USE THE TRIGONOMETRIC TABLES

Since the printing and general method of use of the trigonometric tables in this book are the same for all, only the tables of natural sines will be described. Remarks concerning certain small differences in detail will be given after this description.

The degrees of angle are in the first column at the left of the page. Immediately at the right of the number giving the number of degrees is the function; thus, in the sine table beside 12° is found 2079. No decimal point is printed, but a decimal point is to be placed before each sine: thus, sin 12° = .2079. Similarly, sin 1° = .0175, sin 78° = .9781. On the same line with each number of degrees, reaching across the page, are the sines of that number of degrees plus different numbers of minutes, the number of minutes being given at the top of each column. Thus, the sine of the angle 12½° or 12° 30′ is on the line with 12° and in the column headed 30′ and the figure is 2164; sin 12° 30′ = .2164. Similarly, the sine of 0° 48 or sin 0° 48′ = .0140, and sin 78° 6′ = .9785.

Columns are given for each 6 minutes, 0′, 6′, 12′, 18′, 24′, etc. In order to find the sines for numbers of minutes not given in these columns, use the separate columns at the far right of the page that contain the numbers to be added to those given in the main columns for each, 1, 2, 3, 4, or 5 additional minutes. Thus, in order to find sin 78° 9′ we must

find what is to be added to the number that is sin 78° 6′. 78° 9′ is 3′ more than 78° 6′, and on the line with 78° in the column at the right of the page headed 3 we find 2. This 2 is to be added to the last figure of the sine of 78° 6′, which is .9785, giving .9787; thus, sin 78° 9′ = .9787. Similarly, sin 78° 3′ = (sin 78° 0′) + (difference for 3′) = .9781 + 2 = .9783; sin 0°59′ = sin 0° 59′ = (sin 0° 54′) = (difference for 5′) = .0157 + 15 = .0172; sin 45° 43′ = .7157 + 2 = .7159; sin 12° 35′ = .2178.

Natural cosines are found in the manner described for sines except that the differences in the columns at the right of the page are to be *subtracted* instead of added. This is due to the fact that the cosine decreases as the angle increases, as appears in the table.

Natural tangents are also found in the manner described for sines when the angle is less than 45°. For 45°–90°, however, the decimals in all columns after the first are to have inserted, before the decimal point, the number appearing before the decimal point in the first column on the same line. Thus, tan 53° 36′ = 1.3564. Similarly, tan 73° 52′ = 3.4564, the 4564 being found in the usual manner.

If the decimal part of a tangent has a bar over the first figure, the number appearing before the decimal point in the first column of the *next* line is to be used. Thus, for tan 71° 48′ we find, on the 71° line and in the 48′ column, 0415. Before this we are to write 3 instead of the 2 that appears beside the 71°; this gives tan 71° 48′ = 3.0415. Similarly, tan 63° 32′ = 2.0086, the 0086 being found in the usual manner.

If we are told or find from calculation that the sine of a certain angle is .2588, we find from the table that the angle that has this sine is 15°. Similarly, the angle whose tangent is 3.7321 is 75°, as seen from the same table. This is found by locating the given sine or tangent in the body of the table and looking for the number of degrees on the same line in the column at the left of the table. In the same way we find, from the tables in this appendix, the angle whose tangent is 1.1792 is 49° 42′, the 1 being found in the first column on the 49° line and the 1792 in the 42′ column on the same line.

If the exact function is not found in the table, the next smaller number is located and the corresponding angle read. To this angle is then added (for sines or tangents) or subtracted (for cosines) the number of minutes at the head of the difference column on the right that contains on the same line the difference between the given value and the smaller value located in the table. Thus, if the sine of a certain angle is .3657, we cannot locate this number in the table directly. The next smaller number that we can find is .3649, which corresponds to 21° 24′, and the difference is 3657 − 3649 = 8, which on the same line in the difference column corresponds to 3 minutes. The angle sought is, therefore, 21° 24′ + 3′ = 21° 27′.

NATURAL SINES

	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′	1	2	3	4	5
0°	0000	0017	0035	0052	0070	0087	0105	0122	0140	0157	3	6	9	12	15
1	0175	0192	0209	0227	0244	0262	0279	0297	0314	0332	3	6	9	12	15
2	0349	0366	0384	0401	0419	0436	0454	0471	0488	0506	3	6	9	12	15
3	0523	0541	0558	0576	0593	0610	0628	0645	0663	0680	3	6	9	12	15
4	0698	0715	0732	0750	0767	0785	0802	0819	0837	0854	3	6	9	12	15
5	0872	0889	0906	0924	0941	0958	0976	0993	1011	1028	3	6	9	12	14
6	1045	1063	1080	1097	1115	1132	1149	1167	1184	1201	3	6	9	12	14
7	1219	1236	1253	1271	1288	1305	1323	1340	1357	1374	3	6	9	12	14
8	1392	1409	1426	1444	1461	1478	1495	1513	1530	1547	3	6	9	12	14
9	1564	1582	1599	1616	1633	1650	1668	1685	1702	1719	3	6	9	12	14
10	1736	1754	1771	1788	1805	1822	1840	1857	1874	1891	3	6	9	12	14
11	1908	1925	1942	1959	1977	1994	2011	2028	2045	2062	3	6	9	11	14
12	2079	2096	2113	2130	2147	2164	2181	2198	2215	2232	3	6	9	11	14
13	2250	2267	2284	2300	2317	2334	2351	2368	2385	2402	3	6	8	11	14
14	2419	2436	2453	2470	2487	2504	2521	2538	2554	2571	3	6	8	11	14
15	2588	2605	2622	2639	2656	2672	2689	2706	2723	2740	3	6	8	11	14
16	2756	2773	2790	2807	2823	2840	2857	2874	2890	2907	3	6	8	11	14
17	2924	2940	2957	2974	2990	3007	3024	3040	3057	3074	3	6	8	11	14
18	3090	3107	3123	3140	3156	3173	3190	3206	3223	3239	3	6	8	11	14
19	3256	3272	3289	3305	3322	3338	3355	3371	3387	3404	3	5	8	11	14
20	3420	3437	3453	3469	3486	3502	3518	3535	3551	3567	3	5	8	11	14
21	3584	3600	3616	3633	3649	3665	3681	3697	3714	3730	3	5	8	11	14
22	3746	3762	3778	3795	3811	3827	3843	3859	3875	3891	3	5	8	11	14
23	3907	3923	3939	3955	3971	3987	4003	4019	4035	4051	3	5	8	11	14
24	4067	4083	4099	4115	4131	4147	4163	4179	4195	4210	3	5	8	11	13
25	4226	4242	4258	4274	4289	4305	4321	4337	4352	4368	3	5	8	11	13
26	4384	4399	4415	4431	4446	4462	4478	4493	4509	4524	3	5	8	10	13
27	4540	4555	4571	4586	4602	4617	4633	4648	4664	4679	3	5	8	10	13
28	4695	4710	4726	4741	4756	4772	4787	4802	4818	4833	3	5	8	10	13
29	4848	4863	4879	4894	4909	4924	4939	4955	4970	4985	3	5	8	10	13
30	5000	5015	5030	5045	5060	5075	5090	5105	5120	5135	3	5	8	10	13
31	5150	5165	5180	5195	5210	5225	5240	5255	5270	5284	2	5	7	10	12
32	5299	5314	5329	5344	5358	5373	5388	5402	5417	5432	2	5	7	10	12
33	5446	5461	5476	5490	5505	5519	5534	5548	5563	5577	2	5	7	10	12
34	5592	5606	5621	5635	5650	5664	5678	5693	5707	5721	2	5	7	10	12
35	5736	5750	5764	5779	5793	5807	5821	5835	5850	5864	2	5	7	10	12
36	5878	5892	5906	5920	5934	5948	5962	5976	5990	6004	2	5	7	9	12
37	6018	6032	6046	6060	6074	6088	6101	6115	6129	6143	2	5	7	9	12
38	6157	6170	6184	6198	6211	6225	6239	6252	6266	6280	2	5	7	9	11
39	6293	6307	6320	6334	6347	6361	6374	6388	6401	6414	2	4	7	9	11
40	6428	6441	6455	6468	6481	6494	6508	6521	6534	6547	2	4	7	9	11
41	6561	6574	6587	6600	6613	6626	6639	6652	6665	6678	2	4	7	9	11
42	6691	6704	6717	6730	6743	6756	6769	6782	6794	6807	2	4	6	9	11
43	6820	6833	6845	6858	6871	6884	6896	6909	6921	6934	2	4	6	8	11
44	6947	6959	6972	6984	6997	7009	7022	7034	7046	7059	2	4	6	8	10

NATURAL SINES

	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′	1	2	3	4	5
45°	7071	7083	7096	7108	7120	7133	7145	7157	7169	7181	2	4	6	8	10
46	7193	7206	7218	7230	7242	7254	7266	7278	7290	7302	2	4	6	8	10
47	7314	7325	7337	7349	7361	7373	7385	7396	7408	7420	2	4	6	8	10
48	7431	7443	7455	7466	7478	7490	7501	7513	7524	7536	2	4	6	8	10
49	7547	7558	7570	7581	7593	7604	7615	7627	7638	7649	2	4	6	8	9
50	7660	7672	7683	7694	7705	7716	7727	7738	7749	7760	2	4	6	7	9
51	7771	7782	7793	7804	7815	7826	7837	7848	7859	7869	2	4	5	7	9
52	7880	7891	7902	7912	7923	7934	7944	7955	7965	7970	2	4	5	7	9
53	7986	7997	8007	8018	8028	8039	8049	8059	8070	8080	2	3	5	7	9
54	8090	8100	8111	8121	8131	8141	8151	8161	8171	8181	2	3	5	7	8
55	8192	8202	8211	8221	8231	8241	8251	8261	8271	8281	2	3	5	7	8
56	8290	8300	8310	8320	8329	8339	8348	8358	8368	8377	2	3	5	6	8
57	8387	8396	8406	8415	8425	8434	8443	8453	8462	8471	2	3	5	6	8
58	8480	8490	8499	8508	8517	8526	8536	8545	8554	8563	2	3	5	6	8
59	8572	8581	8590	8599	8607	8616	8625	8634	8643	8652	1	3	4	6	7
60	8660	8669	8678	8686	8695	8704	8712	8721	8729	8738	1	3	4	6	7
61	8746	8755	8763	8771	8780	8788	8796	8805	8813	8821	1	3	4	6	7
62	8829	8838	8846	8854	8862	8870	8878	8886	8894	8902	1	3	4	5	7
63	8910	8918	8926	8934	8942	8949	8957	8965	8973	8980	1	3	4	5	6
64	8988	8996	9003	9011	9018	9026	9033	9041	9048	9056	1	3	4	5	6
65	9063	9070	9078	9085	9092	9100	9107	9114	9121	9128	1	2	4	5	6
66	9135	9143	9150	9157	9164	9171	9178	9184	9191	9198	1	2	3	5	6
67	9205	9212	9219	9225	9232	9239	9245	9252	9259	9265	1	2	3	4	6
68	9272	9278	9285	9291	9298	9304	9311	9317	9323	9330	1	2	3	4	5
69	9336	9342	9348	9354	9361	9367	9373	9379	9385	9391	1	2	3	4	5
70	9397	9403	9409	9415	9421	9426	9432	9438	9444	9449	1	2	3	4	5
71	9455	9461	9466	9472	9478	9483	9489	9494	9500	9505	1	2	3	4	5
72	9511	9516	9521	9527	9532	9537	9542	9548	9553	9558	1	2	3	4	4
73	9563	9568	9573	9578	9583	9588	9593	9598	9603	9608	1	2	2	3	4
74	9613	9617	9622	9627	9632	9636	9641	9646	9650	9655	1	2	2	3	4
75	9659	9664	9668	9673	9677	9681	9686	9690	9694	9699	1	1	2	3	4
76	9703	9707	9711	9715	9720	9724	9728	9732	9736	9740	1	1	2	3	3
77	9744	9748	9751	9755	9759	9763	9767	9770	9774	9778	1	1	2	3	3
78	9781	9785	9789	9792	9796	9799	9803	9806	9810	9813	1	1	2	2	3
79	9816	9820	9823	9826	9829	9833	9836	9839	9842	9845	1	1	2	2	3
80	9848	9851	9854	9857	9860	9863	9866	9869	9871	9874	0	1	1	2	2
81	9877	9880	9882	9885	9888	9890	9893	9895	9898	9900	0	1	1	2	2
82	9903	9905	9907	9910	9912	9914	9917	9919	9921	9923	0	1	1	2	2
83	9925	9928	9930	9932	9934	9936	9938	9940	9942	9943	0	1	1	1	2
84	9945	9947	9949	9951	9952	9954	9956	9957	9959	9960	0	1	1	1	1
85	9962	9963	9965	9966	9968	9969	9971	9972	9973	9974	0	0	1	1	1
86	9976	9977	9978	9979	9980	9981	9982	9983	9984	9985	0	0	1	1	1
87	9986	9987	9988	9989	9990	9990	9991	9992	9993	9993	0	0	0	1	1
88	9994	9995	9995	9996	9996	9997	9997	9997	9998	9998	0	0	0	0	0
89	9998	9999	9999	9999	9999	1,000 nearly	1,000 nearly	1,000 nearly	1,000 nearly	1,000 nearly	0	0	0	0	0

NATURAL COSINES

	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′	1	2	3	4	5
0′	1.000	1.000 nearly	1.000 nearly	1.000 nearly	1.000 nearly	9999	9999	9999	9999	9999	0	0	0	0	0
1	9998	9998	9998	9997	9997	9997	9996	9996	9995	9995	0	0	0	0	0
2	9994	9993	9993	9992	9991	9990	9990	9989	9988	9987	0	0	0	1	1
3	9986	9985	9984	9983	9982	9981	9980	9979	9978	9977	0	0	1	1	1
4	9976	9974	9973	9972	9971	9969	9968	9966	9965	9963	0	0	1	1	1
5	9962	9960	9959	9957	9956	9954	9952	9951	9949	9947	0	1	1	1	2
6	9945	9943	9942	9940	9938	9936	9934	9932	9930	9928	0	1	1	1	2
7	9925	9923	9921	9919	9917	9914	9912	9910	9907	9905	0	1	1	2	2
8	9903	9900	9898	9895	9893	9890	9888	9885	9882	9880	0	1	1	2	2
9	9877	9874	9871	9869	9866	9863	9860	9857	9854	9851	0	1	1	2	2
10	9848	9845	9842	9839	9836	9833	9829	9826	9823	9820	1	1	2	2	3
11	9816	9813	9810	9806	9803	9799	9796	9792	9789	9785	1	1	2	2	3
12	9781	9778	9774	9770	9767	9763	9759	9755	9751	9748	1	1	2	3	3
13	9744	9740	9736	9732	9728	9724	9720	9715	9711	9707	1	1	2	3	3
14	9703	9699	9694	9690	9686	9681	9677	9673	9668	9664	1	1	2	3	4
15	9659	9655	9650	9646	9641	9636	9632	9627	9622	9617	1	2	2	3	4
16	9613	9608	9603	9598	9593	9588	9583	9578	9573	9568	1	2	2	3	4
17	9563	9558	9553	9548	9542	9537	9532	9527	9521	9516	1	2	3	4	4
18	9511	9505	9500	9494	9489	9483	9478	9472	9466	9461	1	2	3	4	5
19	9455	9449	9444	9438	9432	9426	9421	9415	9409	9403	1	2	3	4	5
20	9397	9391	9385	9379	9373	9367	9361	9354	9348	9342	1	2	3	4	5
21	9336	9330	9323	9317	9311	9304	9298	9291	9285	9278	1	2	3	4	5
22	9272	9265	9259	9252	9245	9239	9232	9225	9219	9212	1	2	3	4	6
23	9205	9198	9191	9184	9178	9171	9164	9157	9150	9143	1	2	3	5	6
24	9135	9128	9121	9114	9107	9100	9092	9085	9078	9070	1	2	4	5	6
25	9063	9056	9048	9041	9033	9026	9018	9011	9003	8996	1	3	4	5	6
26	8988	8980	8973	8965	8957	8949	8942	8934	8926	8918	1	3	4	5	6
27	8910	8902	8894	8886	8878	8870	8862	8854	8846	8838	1	3	4	5	7
28	8829	8821	8813	8805	8796	8788	8780	8771	8763	8755	1	3	4	6	7
29	8746	8738	8729	8721	8712	8704	8695	8686	8678	8669	1	3	4	6	7
30	8660	8652	8643	8634	8625	8616	8607	8599	8590	8581	1	3	4	6	7
31	8572	8563	8554	8545	8536	8526	8517	8508	8499	8490	2	3	5	6	8
32	8480	8471	8462	8453	8443	8434	8425	8415	8406	8396	2	3	5	6	8
33	8387	8377	8368	8358	8348	8339	8329	8320	8310	8300	2	3	5	6	8
34	8290	8281	8271	8261	8251	8241	8231	8221	8211	8202	2	3	5	7	8
35	8192	8181	8171	8161	8151	8141	8131	8121	8111	8100	2	3	5	7	8
36	8090	8080	8070	8059	8049	8039	8028	8018	8007	7997	2	3	5	7	9
37	7986	7976	7965	7955	7944	7934	7923	7912	7902	7891	2	4	5	7	9
38	7880	7869	7859	7848	7837	7826	7815	7804	7793	7782	2	4	5	7	9
39	7771	7760	7749	7738	7727	7716	7705	7694	7683	7672	2	4	6	7	9
40	7660	7649	7638	7627	7615	7604	7593	7581	7570	7559	2	4	6	8	9
41	7547	7536	7524	7513	7501	7490	7478	7466	7455	7443	2	4	6	8	10
42	7431	7420	7408	7396	7385	7373	7361	7349	7337	7325	2	4	6	8	10
43	7314	7302	7290	7278	7266	7254	7242	7230	7218	7206	2	4	6	8	10
44	7193	7181	7169	7157	7145	7133	7120	7108	7096	7083	2	4	6	8	10

N.B.—Numbers in difference columns to be subtracted, not added.

NATURAL COSINES

	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′	1	2	3	4	5
45°	7071	7059	7046	7034	7022	7009	6997	6984	6972	6959	2	4	6	8	10
46	6947	6934	6921	6909	6896	6884	6871	6858	6845	6833	2	4	6	8	11
47	6820	6807	6794	6782	6769	6756	6743	6730	6717	6704	2	4	6	9	11
48	6691	6678	6665	6652	6639	6626	6613	6600	6587	6574	2	4	7	9	11
49	6561	6547	6534	6521	6508	6494	6481	6468	6455	6441	2	4	7	9	11
50	6428	6414	6401	6388	6374	6361	6347	6334	6320	6307	2	4	7	9	11
51	6293	6280	6266	6252	6239	6225	6211	6198	6184	6170	2	5	7	9	11
52	6157	6143	6129	6115	6101	6088	6074	6060	6046	6032	2	5	7	9	12
53	6018	6004	5990	5976	5962	5948	5934	5920	5906	5892	2	5	7	9	12
54	5878	5864	5850	5835	5821	5807	5793	5779	5764	5750	2	5	7	9	12
55	5736	5721	5707	5693	5678	5664	5650	5635	5621	5606	2	5	7	10	12
56	5592	5577	5563	5548	5534	5519	5505	5490	5476	5461	2	5	7	10	12
57	5446	5432	5417	5402	5388	5373	5358	5344	5329	5314	2	5	7	10	12
58	5299	5284	5270	5255	5240	5225	5210	5195	5180	5165	2	5	7	10	12
59	5150	5135	5120	5105	5090	5075	5060	5045	5030	5015	3	5	8	10	13
60	5000	4985	4970	4955	4939	4924	4909	4894	4879	4863	3	5	8	10	13
61	4848	4833	4818	4802	4787	4772	4756	4741	4726	4710	3	5	8	10	13
62	4695	4679	4664	4648	4633	4617	4602	4586	4571	4555	3	5	8	10	13
63	4540	4524	4509	4493	4478	4462	4446	4431	4415	4399	3	5	8	10	13
64	4384	4368	4352	4337	4321	4305	4289	4274	4258	4242	3	5	8	10	13
65	4226	4210	4195	4179	4163	4147	4131	4115	4099	4083	3	5	8	11	13
66	4067	4051	4035	4019	4003	3987	3971	3955	3939	3923	3	5	8	11	14
67	3907	3891	3875	3859	3843	3827	3811	3795	3778	3762	3	5	8	11	14
68	3746	3730	3714	3697	3681	3665	3649	3633	3616	3600	3	5	8	11	14
69	3584	3567	3551	3535	3518	3502	3486	3469	3453	3437	3	5	8	11	14
70	3420	3404	3387	3371	3355	3338	3322	3305	3289	3272	3	5	8	11	14
71	3256	3239	3223	3206	3190	3173	3156	3140	3123	3107	3	6	8	11	14
72	3090	3074	3057	3040	3024	3007	2990	2974	2957	2940	3	6	8	11	14
73	2924	2907	2890	2874	2857	2840	2823	2807	2790	2773	3	6	8	11	14
74	2756	2740	2723	2706	2689	2672	2656	2639	2622	2605	3	6	8	11	14
75	2588	2571	2554	2538	2521	2504	2487	2470	2453	2436	3	6	8	11	14
76	2419	2402	2385	2368	2351	2334	2317	2300	2284	2267	3	6	8	11	14
77	2250	2233	2215	2198	2181	2164	2147	2130	2113	2096	3	6	9	11	14
78	2079	2062	2045	2028	2011	1994	1977	1959	1942	1925	3	6	9	11	14
79	1908	1891	1874	1857	1840	1822	1805	1788	1771	1754	3	6	9	12	14
80	1736	1719	1702	1685	1668	1650	1633	1616	1599	1582	3	6	9	12	14
81	1564	1547	1530	1513	1495	1478	1461	1444	1426	1409	3	6	9	12	14
82	1392	1374	1357	1340	1323	1305	1288	1271	1253	1236	3	6	9	12	14
83	1219	1201	1184	1167	1149	1132	1115	1097	1080	1063	3	6	9	12	14
84	1045	1028	1011	0993	0976	0958	0941	0924	0906	0889	3	6	9	12	14
85	0872	0854	0837	0819	0802	0785	0767	0750	0732	0715	3	6	9	12	15
86	0698	0680	0663	0645	0628	0610	0593	0576	0558	0541	3	6	9	12	15
87	0523	0506	0488	0471	0454	0436	0419	0401	0384	0366	3	6	9	12	15
88	0349	0332	0314	0297	0279	0262	0244	0227	0209	0192	3	6	9	12	15
89	0175	0157	0140	0122	0105	0087	0070	0052	0035	0017	3	6	9	12	15

N.B.—Numbers in difference columns to be subtracted, not added.

NATURAL TANGENTS

	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′	1	2	3	4	5
0°	.0000	0017	0035	0052	0070	0087	0105	0122	0140	0157	3	6	9	12	14
1	.0175	0192	0209	0227	0244	0262	0279	0297	0314	0332	3	6	9	12	15
2	.0349	0367	0384	0402	0419	0437	0454	0472	0489	0507	3	6	9	12	15
3	.0524	0542	0559	0577	0594	0612	0629	0647	0664	0682	3	6	9	12	15
4	.0699	0717	0734	0752	0769	0787	0805	0822	0840	0857	3	6	9	12	15
5	.0875	0892	0910	0928	0945	0963	0981	0998	1016	1033	3	6	9	12	15
6	.1051	1069	1086	1104	1122	1139	1157	1175	1192	1210	3	6	9	12	15
7	.1228	1246	1263	1281	1299	1317	1334	1352	1370	1388	3	6	9	12	15
8	.1405	1423	1441	1459	1477	1495	1512	1530	1548	1566	3	6	9	12	15
9	.1584	1602	1620	1638	1655	1673	1691	1709	1727	1745	3	6	9	12	15
10	.1763	1781	1799	1817	1835	1853	1871	1890	1908	1926	3	6	9	12	15
11	.1944	1962	1980	1998	2016	2035	2053	2071	2089	2107	3	6	9	12	15
12	.2126	2144	2162	2180	2199	2217	2235	2254	2272	2290	3	6	9	12	15
13	.2309	2327	2345	2364	2382	2401	2419	2438	2456	2475	3	6	9	12	15
14	.2493	2512	2530	2549	2568	2586	2605	2623	2642	2661	3	6	9	12	16
15	.2679	2698	2717	2736	2754	2773	2792	2811	2830	2849	3	6	9	13	16
16	.2867	2886	2905	2924	2943	2962	2981	3000	3019	3038	3	6	9	13	16
17	.3057	3076	3096	3115	3134	3153	3172	3191	3211	3230	3	6	10	13	16
18	.3249	3269	3288	3307	3327	3346	3365	3385	3404	3424	3	6	10	13	16
19	.3443	3463	3482	3502	3522	3541	3561	3581	3600	3620	3	6	10	13	17
20	.3640	3659	3679	3699	3719	3739	3759	3779	3799	3819	3	7	10	13	17
21	.3839	3859	3879	3899	3919	3939	3959	3978	4000	4020	3	7	10	13	17
22	.4040	4061	4081	4101	4122	4142	4163	4183	4204	4224	3	7	10	14	17
23	.4245	4265	4286	4307	4327	4348	4369	4390	4411	4431	3	7	10	14	17
24	.4452	4473	4494	4515	4536	4557	4578	4599	4621	4642	4	7	10	14	18
25	.4663	4684	4706	4727	4748	4770	4791	4813	4834	4856	4	7	11	14	18
26	.4877	4899	4921	4942	4964	4986	5008	5029	5051	5073	4	7	11	15	18
27	.5095	5117	5139	5161	5184	5206	5228	5250	5272	5295	4	7	11	15	18
28	.5317	5340	5362	5384	5407	5430	5452	5475	5498	5520	4	8	11	15	19
29	.5543	5566	5589	5612	5635	5658	5681	5704	5727	5750	4	8	12	15	19
30	.5774	5797	5820	5844	5867	5890	5914	5938	5961	5985	4	8	12	16	20
31	.6009	6032	6056	6080	6104	6128	6152	6176	6200	6224	4	8	12	16	20
32	.6249	6273	6297	6322	6346	6371	6395	6420	6445	6469	4	8	12	16	20
33	.6494	6519	6544	6569	6594	6619	6644	6669	6694	6720	4	8	13	17	21
34	.6745	6771	6796	6822	6847	6873	6899	6924	6950	6976	4	9	13	17	21
35	.7002	7028	7054	7080	7107	7133	7159	7186	7212	7239	4	9	13	18	22
36	.7265	7292	7319	7346	7373	7400	7427	7454	7481	7508	5	9	14	18	23
37	.7536	7563	7590	7618	7646	7673	7701	7729	7757	7785	5	9	14	18	23
38	.7813	7841	7869	7898	7926	7954	7983	8012	8040	8069	5	10	14	19	24
39	.8098	8127	8156	8185	8214	8243	8273	8302	8332	8361	5	10	15	20	24
40	.8391	8421	8451	8481	8511	8541	8571	8601	8632	8662	5	10	15	20	25
41	.8693	8724	8754	8785	8816	8847	8878	8910	8941	8972	5	10	16	21	26
42	.9004	9036	9067	9099	9131	9163	9195	9228	9260	9293	5	11	16	21	27
43	.9325	9358	9391	9424	9457	9490	9523	9556	9590	9623	6	11	17	22	28
44	.9657	9691	9725	9759	9793	9827	9861	9896	9930	9965	6	11	17	23	29

NATURAL TANGENTS

	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′	1	2	3	4	5
45°	1.0000	0035	0070	0105	0141	0176	0212	0247	0283	0319	6	12	18	24	30
46	1.0355	0392	0428	0464	0501	0538	0575	0612	0649	0686	6	12	18	25	31
47	1.0724	0761	0799	0837	0875	0913	0951	0990	1028	1067	6	13	19	25	32
48	1.1106	1145	1184	1224	1263	1303	1343	1383	1423	1463	7	13	20	26	33
49	1.1504	1544	1585	1626	1667	1708	1750	1792	1833	1875	7	14	21	28	34
50	1.1918	1960	2002	2045	2088	2131	2174	2218	2261	2305	7	14	22	29	36
51	1.2349	2393	2437	2482	2527	2572	2617	2662	2708	2753	8	15	23	30	38
52	1.2799	2846	2892	2938	2985	3032	3079	3127	3175	3222	8	16	23	31	39
53	1.3270	3319	3367	3416	3465	3514	3564	3613	3663	3713	8	16	25	33	41
54	1.3764	3814	3865	3916	3968	4019	4071	4124	4176	4229	9	17	26	34	43
55	1.4281	4335	4388	4442	4496	4550	4605	4659	4715	4770	9	18	27	36	45
56	1.4826	4882	4938	4994	5051	5108	5166	5224	5282	5340	10	19	29	38	48
57	1.5399	5458	5517	5577	5637	5697	5757	5818	5880	5941	10	20	30	40	50
58	1.6003	6066	6128	6191	6255	6319	6383	6447	6512	6577	11	21	32	43	53
59	1.6643	6709	6775	6842	6909	6977	7045	7113	7182	7251	11	23	34	45	56
60	1.7321	7391	7461	7532	7603	7675	7747	7820	7893	7966	12	24	36	48	60
61	1.8040	8115	8190	8265	8341	8418	8495	8572	8650	8728	13	26	38	51	64
62	1.8807	8887	8967	9047	9128	9210	9292	9375	9458	9542	14	27	41	55	68
63	1.9626	9711	9797	9883	9970	$\bar{0}057$	$\bar{0}145$	$\bar{0}233$	$\bar{0}323$	$\bar{0}413$	15	29	44	58	73
64	2.0503	0594	0686	0778	0872	0965	1060	1155	1251	1348	16	31	47	63	78
65	2.1445	1543	1642	1742	1842	1943	2045	2148	2251	2355	17	34	51	68	85
66	2.2460	2566	2673	2781	2889	2998	3109	3220	3332	3445	18	37	55	74	92
67	2.3559	3673	3789	3906	4023	4142	4262	4383	4504	4627	20	40	60	79	99
68	2.4751	4876	5002	5129	5257	5386	5517	5649	5782	5916	22	43	65	87	108
69	2.6015	6187	6325	6464	6605	6746	6889	7034	7179	7326	24	47	71	95	118
70	2.7475	7625	7776	7929	8083	8239	8397	8556	8716	8878	26	52	78	104	130
71	2.9042	9208	9375	9544	9714	9887	$\bar{0}061$	$\bar{0}237$	$\bar{0}415$	$\bar{0}595$	29	58	87	115	144
72	3.0777	0961	1146	1334	1524	1716	1910	2106	2305	2506	32	64	96	129	161
73	3.2709	2914	3122	3332	3544	3759	3977	4197	4420	4646	36	72	108	144	180
74	3.4874	5105	5339	5576	5816	6059	6305	6554	6806	7062	41	82	122	162	203
75	3.7321	7583	7848	8118	8391	8667	8947	9232	9520	9812	46	94	139	186	232
76	4.0108	0408	0713	1022	1335	1653	1976	2303	2635	2972	53	107	160	214	267
77	4.3315	3662	4015	4374	4737	5107	5483	5864	6252	6646	62	124	186	248	310
78	4.7046	7453	7867	8288	8716	9152	9594	$\bar{0}045$	$\bar{0}504$	$\bar{0}970$	73	146	219	292	365
79	5.1446	1929	2422	2924	3435	3955	4486	5026	5578	6140	87	175	262	350	437
80	5.6713	7297	7894	8502	9124	9758	$\bar{0}405$	$\bar{1}066$	$\bar{1}742$	$\bar{2}432$					
81	6.3138	3859	4596	5350	6122	6912	7920	8548	9395	$\bar{0}264$					
82	7.1154	2066	3002	3962	4947	5958	6996	8062	9158	$\bar{0}285$					
83	8.1443	2636	3863	5126	6427	7769	9152	$\bar{0}579$	$\bar{2}052$	$\bar{3}572$					
84	9.5144	9.677	9.845	10.02	10.20	10.39	10.58	10.78	10.99	11.20					
85	11.43	11.66	11.91	12.16	12.43	12.71	13.00	13.30	13.62	13.95					
86	14.30	14.67	15.06	15.46	15.89	16.35	16.83	17.34	17.89	18.46					
87	19.08	19.74	20.45	21.20	22.02	22.90	23.86	24.90	26.03	27.27					
88	28.64	30.14	31.82	33.69	35.80	38.19	40.92	44.07	47.74	52.08					
89	57.29	63.66	71.62	81.85	95.49	114.6	143.2	191.0	286.5	573.0					

Difference columns cease to be useful, owing to the rapidity with which the value of the tangent changes.

Tables are taken from J. E. Thompson, *Trigonometry for the Practical Man*. Princeton, N.J.: D. Van Nostrand, 1962.

Notes

CHAPTER 1

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3. Feininger, *The Complete Photographer.*
4. Feininger, *The Complete Photographer,* p 40.
5. Betts, *Essentials of Applied Physics.*
6. Baines, *Science of Photography.*
7. Adams, *The Camera.*
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10. Adams, p 40.
11. Adams, p 12.
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13. Baines, p 105.
14. Betts, p 25.
15. Henson, *Binoculars, Telescopes and Telescopic Sights.*
16. Henson, p 319.
17. Adams, p 19.
18. Klein and Furtak, *Optics.*
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CHAPTER 2

1. Braunstein, *Depth Perception Through Motion,* p. 69.
2. Braunstein, p. 37.

Film/Video

OPTICS AND FOCUS
FOR CAMERA ASSISTANTS
ART, SCIENCE and Zen

FRITZ LYNN HERSHEY

Once camera assistants have learned and practiced the rules of their job, they can then begin to explore and test their limits. Relying on theory as well as hands-on experience, ***Optics and Focus for Camera Assistants*** melds technical knowledge and skills with techniques and attitudes to provide key information on one of the most vital parts of a camera assistant's job: focusing. Assistants will learn how to make themselves invaluable on the set by being able to apply theoretical approaches to problem solving. This will allow them to extrapolate from theory to any practical situation rather than following cookbook-style solutions. ***Optics and Focus for Camera Assistants*** also stresses enhanced techniques for greater speed and precision in routine equipment-handling procedures.

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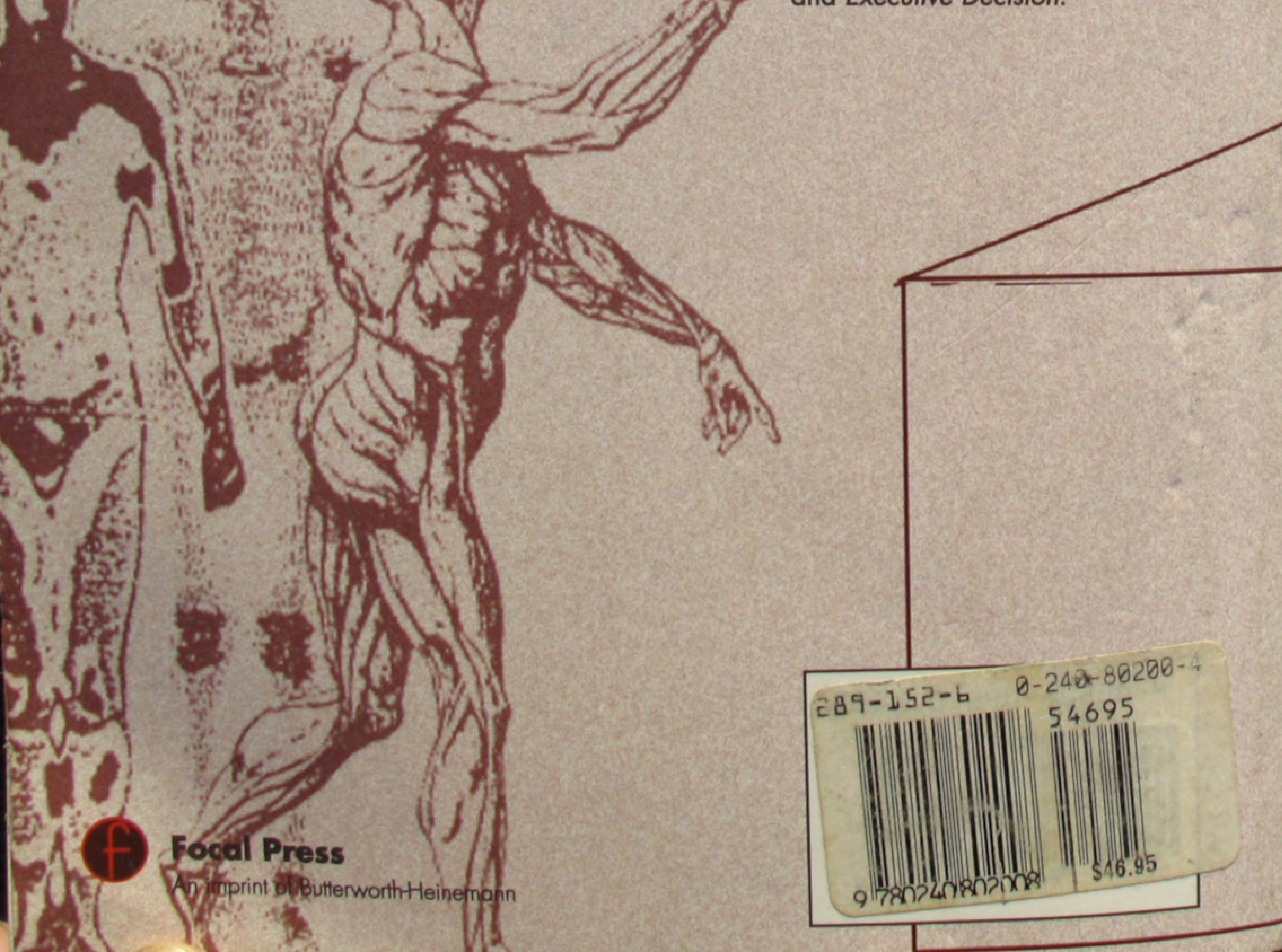
Fritz Lynn Hershey has been a freelance camera assistant for more than 15 years, working principally on commercials. His feature film credits include *Year of the Dragon* and *Executive Decision*.



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